THE EVOLUTION OF PESCADERO MARSH

A thesis submitted to the faculty of
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requirements for the
degree
Master of Arts.

by

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CERTIFICATION OF APPROVAL

I certify that I have read THE EVOLUTION OF PESCADERO MARSH by FRANK SALVATORE VIOLLIS, and that in my opinion this work meets the criteria for approving a thesis submitted in partial fulfillment of requirements for the Master of Arts degree at San Francisco State University.

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The purpose of this study is to better understand the origin and evolution of Pescadero Marsh. The physical and biological nature of the marsh will be described and human influences determined.

This will be accomplished by applying several standard geographical, geological and biological field and laboratory techniques. Cores were taken producing a stratigraphic picture of the marsh deposits. A Carbon 14 date was obtained from the peat deposits, which assisted in determining the rate of sedimentation. Water and soil salinity tests helped determine the relationship of marsh plants to varying degrees of salinity. Distribution maps of physical and biological phenomena were prepared.

Old maps, photographs, written accounts, as well as interviews with local residents, produced an historical perspective.

This study was undertaken because Pescadero Marsh is one of California's unique and valuable natural resources, and a study of the area was lacking. This investigation is only one of many that should be undertaken at Pescadero. Hopefully others will decide to further our knowledge of this remarkable marsh.

ACKNOWLEDGMENTS

To all those who have come to appreciate Pescadero Marsh, and my parents and friends who offered encouragement throughout my studies.

The scope of this thesis has expanded far beyond the original plan. During the evolution of this work many people have generously given me encouragement, guidance, and in some cases, a good deal of their personal time and energy. I thank all of them and I hope together we have created a valuable document for future research.

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CHAPTER 1

PESCADERO MARSH SETTING

Introduction

My acquaintance with Pescadero Marsh and the surrounding area began eight years ago. Since that time I have lived and worked in the Pescadero area on two separate occasions. It is because of my familiarity with the land and people of the region, along with a deep love for its seemingly unchanging nature, that I decided to do this work.

Pescadero does not appear to have had as large an Indian population as Ano Nuevo 11 miles to the south, or the larger Spanishtown settlement 15 miles north. Pescadero has only supported a small number of Indians, Mexican-Spanish, and early Anglo-Americans. Therefore, very little historical material exists; the available information is largely limited to the American period.

The importance of the marsh as a nursery for steelhead and salmon as well as a sanctuary for birds was perhaps indirectly appreciated by the earlier hunters and fishermen. However, the marsh itself was never considered of major importance by those who wrote the history of the coastside lands. This omission is not surprising, because only recently have we come to understand and appreciate the importance of coastal marshlands.

Historically, western cultures have viewed marshes, swamps, and other wetland habitats as reservoirs of disease or as potential agricultural lands. The draining and or filling in of wetland was considered to be an improvement to the total quality of the environment. The practice of draining inland accumulations of water for the purpose of bringing new land under cultivation was adopted after the middle of the fifteenth century in Europe. However, the destruction of coastal wetlands had begun as early as the thirteenth century when the Lowlanders in northwest Europe constructed dikes at the edge of the sea (Marsh, 1864).

In these earlier times it was believed that nearby forests protected the inhabitants from the "pestilential and wholly unproductive marshes" (Marsh, 1874). The forests and other vegetation formed a screen against the "bad air" rising from the marshes, the expected source of disease. Even George Perkins Marsh, who was acquainted with the natural processes of the earth, was skeptical about this little known environment. He wrote in 1874, "The fact that the mixing of salt and fresh in coast marshes and lagoons is deleterious to the sanitary conditions of the vicinity has been generally admitted, though the precise reason why a mixture of both should be more injurious than either alone is not altogether clear."

The more recent decline of wetlands is primarily due to economic pressures. California coastal marshes were once more extensive than they are at present. In the San Francisco Bay alone, 60 percent reduction of peripheral marshlands occurred between 1850 and 1968 (MacDonald, 1977).

It is estimated that approximately 90,000 acres of salt marsh remain along the California coast. Of the 90,000 acres, almost 90 percent is within the giant San Francisco Bay complex. Another

4 to 5 percent occurs north of San Francisco, while the remaining marshes lie along the coast between San Francisco and Mexico (MacDonald, 1977).

Figure 1 shows the distribution of California's coastal salt marshes. Included in the distribution are those saltwater marshes found in protected shallow bays, estuaries and coastal lagoons. The physical and biological nature of these marshes differ, upon the degree of exposure to oceanic influences.

It is interesting to note that Pescadero Marsh is not included in Figure 1. This neglect further emphasizes the fact that very little has been known about the area. While the 500 acres of Pescadero Marsh admittedly represent a small fraction of the total California marsh system, the important location near large centers of population makes it an exceptionally valuable resource.

In relation to the surrounding lands and communities, it is evident that only subtle changes have taken place in the immediate vicinity of Pescadero Marsh. Yet, in this age of exponential growth, Pescadero may succumb to the same population pressures that exist in other nearby areas, like Half Moon Bay. We do not know what effects the advancement of the modern age will have on this delicate and attractive marsh ecosystem.

Location

Pescadero Marsh is located along the Pacific coast in the southwestern portion of San Mateo County California, approximately

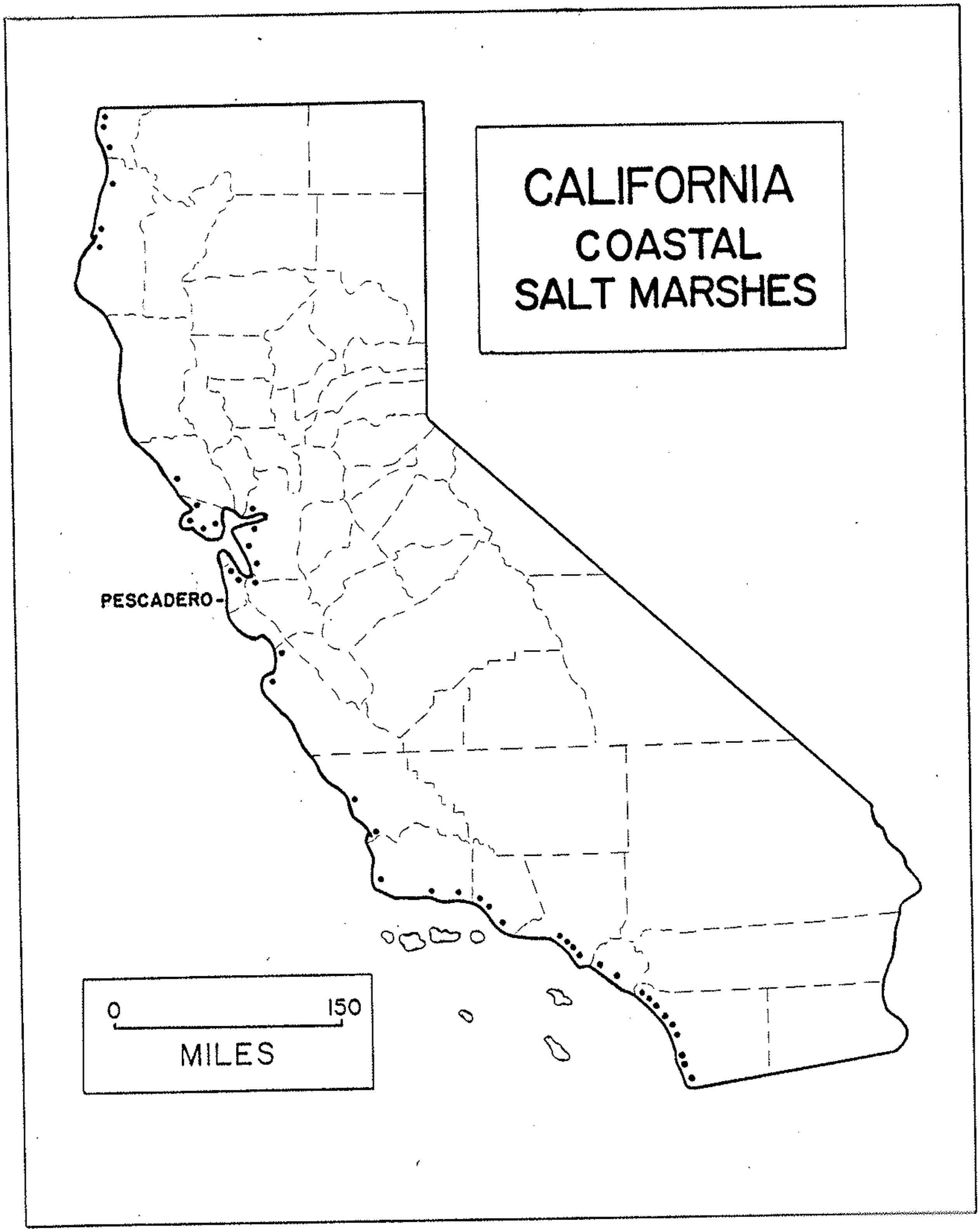


Figure 1. Distribution of California Salt Marshes (after MacDonald, 1977).

40 miles south of San Francisco (Figures 2 and 3). At 122° 248 West Longitude and 37° 168 North Latitude, the marsh can be located on the San Gregorio Quadrangle, California-San Mateo County map (U.S.G.S. Topographic, 7.5 minute series).

The town of Pescadero (population approximately 500) lies one mile to the east of the marsh. Pigeon Point lighthouse is located on the coast approximately 5.5 miles to the south.

The confluence of Pescadero and Butano Creeks is centrally located within the marsh system, about 1/4 mile east of the mouth or coastal outlet.

Present Status of Pescadero Marsh

Pescadero Marsh has the typical characteristics of a "high" coastal salt marsh. A high coastal salt marsh is characterized by the dominance of *Salicornia* sp. (pickleweed) and the absence of *Spartina* sp. (cordgrass) (MacDonald, 1977). Much of the water in the marsh is brackish, although the southeastern portion is largely fresh.

The development of a sandbar at the mouth of Pescadero Creek prohibits the free mixing of fluvial (terrestrial) and littoral (oceanic) waters during much of the year. Only when streamflow is sufficient and the wave action strong enough, is the sandbar temporarily removed allowing the mixing of waters. During this time an estuarine condition exists in the lagoon. Estuaries may form at the mouths of coastal rivers when tidal effects permit sea water and fresh water to mix (Moore, 1968).

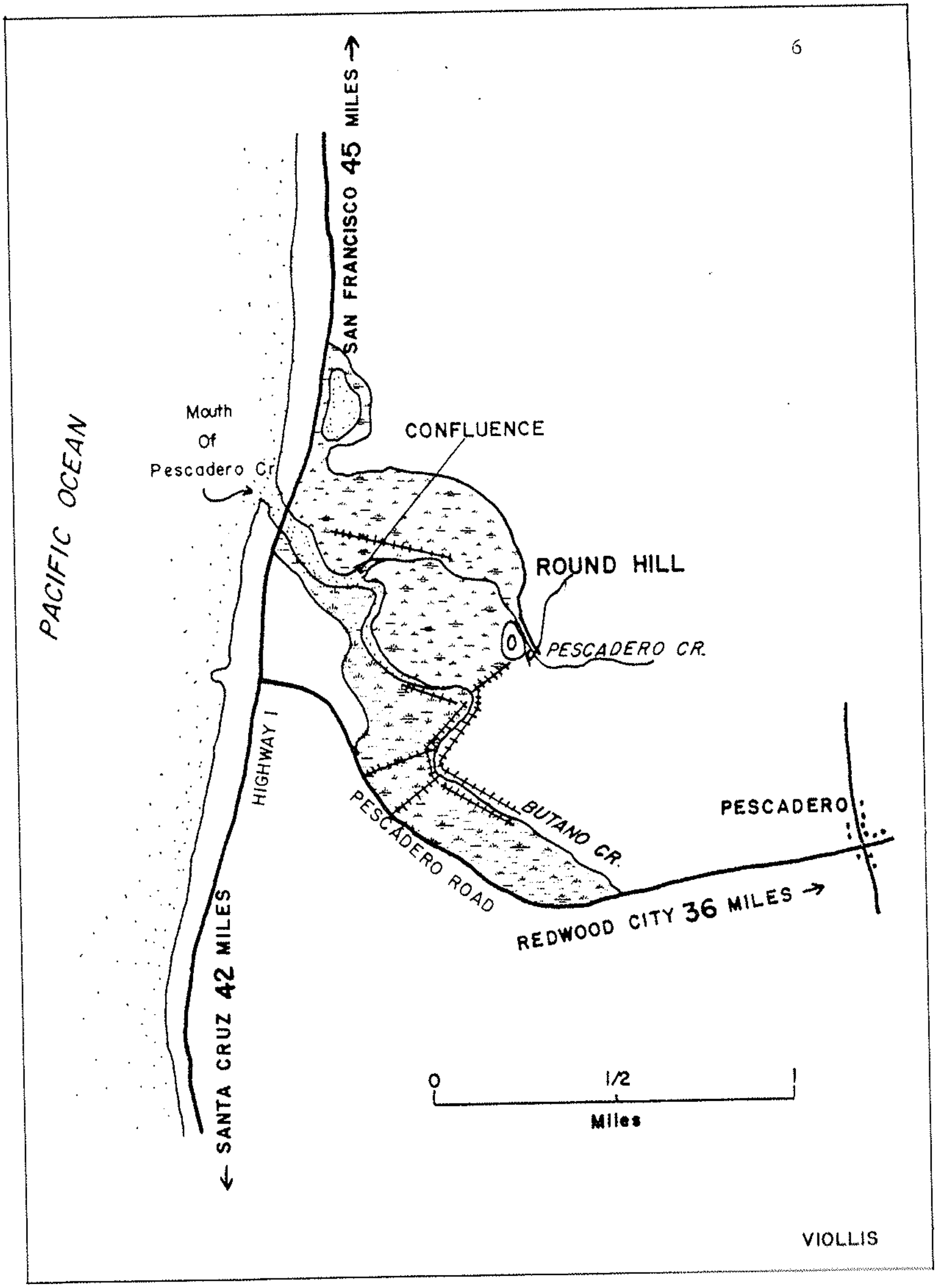


Figure 2. Map of Pescadero Marsh and its relationship to population centers.

Figure 3. 1970 aerial photo of Pescadero Marsh, scale 1:24,000 (2.64 inches = 1 mile) (Western Air Photos, Redwood City, California).

The precise conditions necessary to open the Pescadero sandbar have not been determined, and this information is needed to better manage the marsh. The biological and physical nature of Pescadero Marsh will be considered in Chapter III.

Although a variety of mammals, reptiles, fish and invertebrates find the marsh a suitable habitat, the shorebirds and waterfowl are the most conspicuous living things. Some of the birds are permanent residents, some breed within the marsh, and others use the marsh during migration.

Pescadero Marsh is the only remaining marshland on the coast between San Francisco and Elkhorn Slough, which is behind Moss Landing in Monterey County. According to Dr. Robert T. Orr of the California Academy of Sciences, the relatively large fresh water portion of this marsh is one of few such areas in central California (oral communication, 27 May 1977).

The State of California has already purchased more than half of the total marsh acreage and the adjoining beach is also owned by the State. A small portion of the marsh is still privately owned by Vincent Muzzi; the area lies along Pescadero Road and encompasses the southeast section of the marsh. Table 1 summarizes the present status of the marsh lands:

Table 1

Acres	Land Type	Classification	Ownership
80.0	Beach & Dune	State Beach	State of California
206.0	Marsh	Natural Preserve	State of California
172.5	Marsh	General Services	State of California
46.5	Agricultural	General Services	State of California
132.25	Marsh & Agricultural	Private Land	Vincent Muzzi

The marsh is frequently used as a study area for a number of outdoor education programs. The San Mateo County Schools, Marin County Schools, San Joaquin County Schools, and Mount Diablo School District all have resident field schools a few miles from the marsh. The schools maintain a full time staff of trained teachers and interns who instruct students in environmental and outdoor education. The study of the marsh, and primarily the birds, is an important part of each program. According to the State Department of Parks and Recreation, these organizations represent the most significant human use of the marsh (oral communication, Roger Wertz, 1978).

Members of several regional chapters of the National Audubon Society use the marsh for study on a regular basis. Other public and private groups, including members of the Santa Cruz Bird Club also frequent the marsh. Bird watching is becoming increasingly popular along the San Mateo coast.

Only a few documented studies have been completed on the flora and fauna of Pescadero Marsh. In 1942, Dr. Robert T. Orr completed "A Study of the Birds of the Big Basin Region of California" which was published in The American Midland Naturalist (Orr, 1942, 27: 273-337). In this paper he briefly described the marsh and listed some bird observations. In 1973, William Anderson and Randy Morgan surveyed the marsh flora and published A Flora of Pescadero Marsh. Bruce Elliot, wildlife biologist for the Department of Fish and Game, has prepared an unpublished paper (1975) on the "Natural Resources of Pescadero Marsh."

Historical Perspective

The historical events of the Pescadero watershed and region are reflected in the present condition at Pescadero Marsh. An historical perspective of the study area will focus upon these events.

Prior to 1769, the date of the first recorded account, Pescadero was probably inhabited by a triblet of Indians known as the Oljone. This small group was part of a larger tribe of Indians known as the Coastanoans, who occupied the region between San Francisco Bay and Point Sur in Monterey County. The Coastanoans consisted of some forty triblets, each having its own territory and lifestyle. Although the languages had a common root, early Europeans found it difficult to discern one from another (Margolin, 1978).

A recent investigation of the Mission records indicates that a village called Pructaca was located near Pescadero (oral communication, Steve Dietz, 2 May 1979). No definite archaeological evidence has been found associating the Indians with the marsh; however, it seems fairly certain that the area was used.

Estuaries and coastal lagoons provide an optimal ecological setting for food production (energy flow). The estuary and surrounding ecological zones, such as freshwater marshes, coastal sage, grassland and chaparral create a series of ecotones (transition zones between plant communities) where the number of species and density of population is greater than in adjoining communities. This increased variety and density at plant community junctions is known as the "edge effect" (Odum, 1971).

A wide range in habitat types occurs between the estuary and the peaks of the coast range, locally known as the skyline. In this area of San Mateo County, the drainage basin is relatively short, about 15 miles from the summits to the seashore. The Indians would have had available to them a good variety of ecological zones for food exploitation.

Surveys of other estuarine environments in California, including San Francisco Bay, indicate a clustering of midden sites (shellmounds) along their shores. It appears that prehistoric populations chose estuarine habitation sites over other coastal locations (DesGrandchamp, 1976).

Robert Schenk made a survey of the upper and lower course of Pescadero Creek in 1969. This study was used by the Army Corps of Engineers, as part of a larger study to determine the feasibility of a dam site at Worley Flats (eight miles east of the marsh). In the upper stream course Schenk did not find any archaeological sites; however, on the lower stream channels and near the marsh he recorded a few areas as "locations of archaeological potential." At these locations, shown in Figure 4, charcoal concentrations and bird bones were found, but he concludes there was "little visible evidence of archaeological sites." He noted that the sedimentation rate is rapid and had taken place over a long period of time. Such rapid sedimentation could have destroyed the sites. He concluded that further site testing would be required (Schenk, 1969).

The most definite evidence of Indian activity near the marsh was derived from the Rivera-Palou Exploration of 1774 (Figure 4). "Near

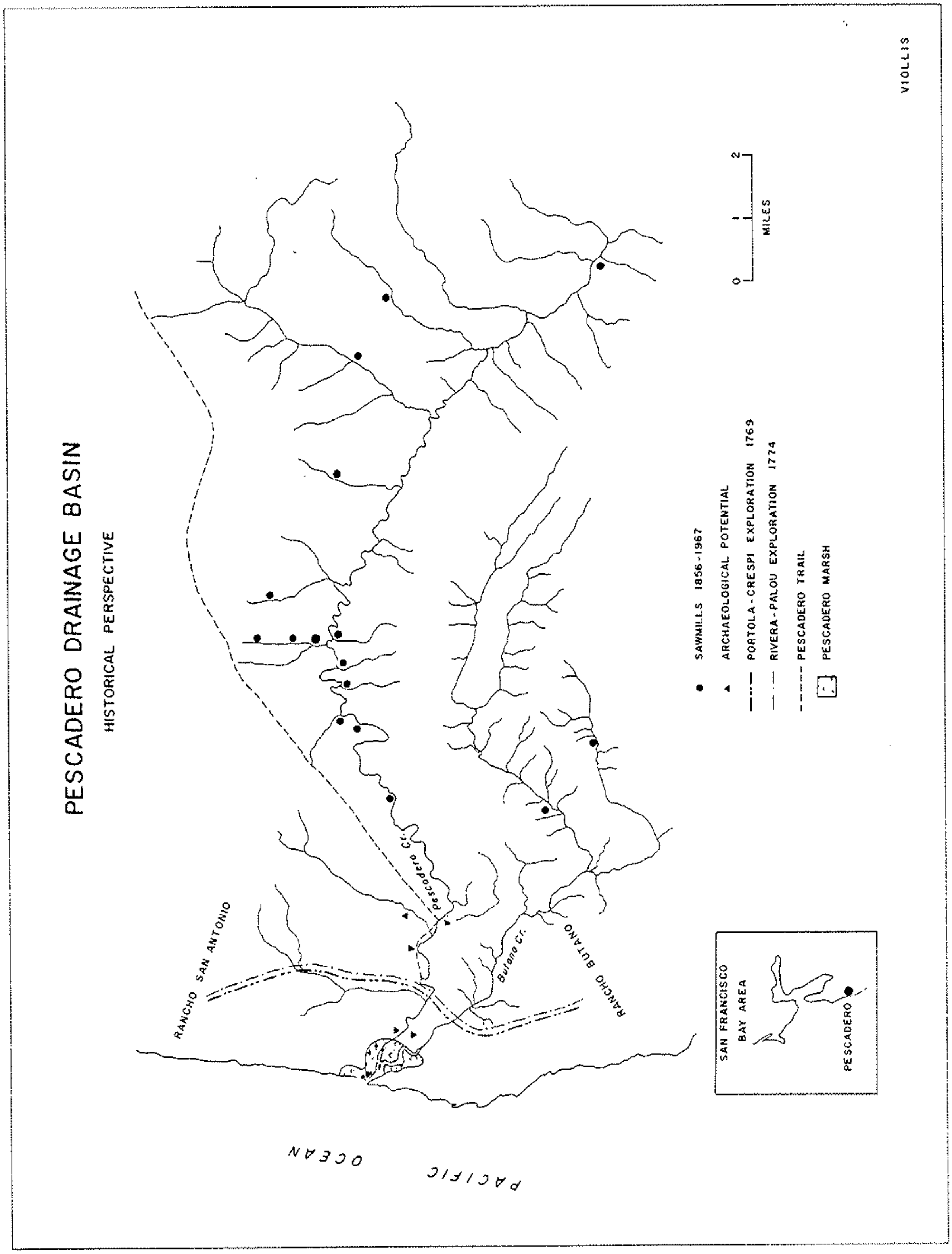


Figure 4. Pescadero Drainage Basin. Historical Perspective.

the first of the two large Arroys (Pescadero) we saw vestiges of a village with its cemetery, in which there was planted two very high, slim and straight poles, at the top of each of which there was hanging a cape made of grass of the kind the heathen use, this being the custom which they have in the burial of their chief" (Bolton, 1930).

It is interesting that the map by Alan K. Brown published in Stanger's "South from San Francisco" shows an Indian village near the present town of Pescadero (Stanger, 1963).

Spanish-Mexican Period. Pescadero Marsh is located on two former Spanish land grants. The largest portion of the marsh is located on the old San Antonio of Pescadero Grant. A small section of the marsh, extending south of Butano Creek, lies on the Butano Grant.

In 1833, when Juan Jose Gonzales petitioned for a grant of land, the region had been used as pasture by Mission Santa Cruz, and had already been known as San Antonio of El Pescadero (Stanger, 1938). The official Mission pasture limits reached from Santa Cruz up the coast to Half Moon Bay and the animals ranged on these lands until 1833-34, when the Mission was secularized and its herds were scattered (Wayburn and Scott, 1974).

Father Antonio Real, recognizing that the Mission lands were about to be reduced in size and the cattle limited, recommended that his mayordromo, Juan Gonzales, receive the land. "Pescadero has been used when the Mission herds were large, but now it is no longer needed. Punta del Ano Nuevo is now the most distant pasture in use (from Santa Cruz). The Mission would like to see Gonzales get the land" (Stanger, 1938).

Juan Gonzales did receive the land and drove about 700 head of cattle and horses from Santa Cruz to Pescadero. The grant totaled 3,282 acres and extended from Butano Creek on the south to Pomponio Creek on the north.

Gonzales was said to have built an adobe near Pescadero Creek in the vicinity of the original Spanish trail. One source located the adobe on the north bank of Pescadero Creek, near the town (Preliminary Report, San Mateo County Planning Department, 1977).

In 1840, his herd prospered to 4,000 head of cattle and 500 horses (Stanger, 1938). In 1852, 800 acres were sold to Eli Moore and the other portions were deeded to his brothers and sister. Figure 5 shows Rhancho Pescadero's boundary in April 1861.

The Butano grant was obtained on a preliminary or incomplete grant in 1838 by Romone Sanchez, widow of Vanascio Galindo. In 1844, the grant was officially legalized. A house and a coral were built near Butano Creek and crops were planted (Stanger, 1938). The grant of 4,438 acres was bordered on the north by the Juan Gonzales property and on the south by Arroyo do Los Frijoles.

In 1866, Manuel Rodriquez acquired the land and received the United States patent. The rhancho was later purchased by Clark and Coburn of San Francisco. Loren Coburn moved to the area in 1872, and was involved in land development; his endeavors have been extensive.

Early American Period. Prior to 1853, the Pescadero area was primarily Spanish speaking with a few small rhanchos. However, in 1853, Alexander Moore of Missouri arrived at Pescadero. Apparently, the

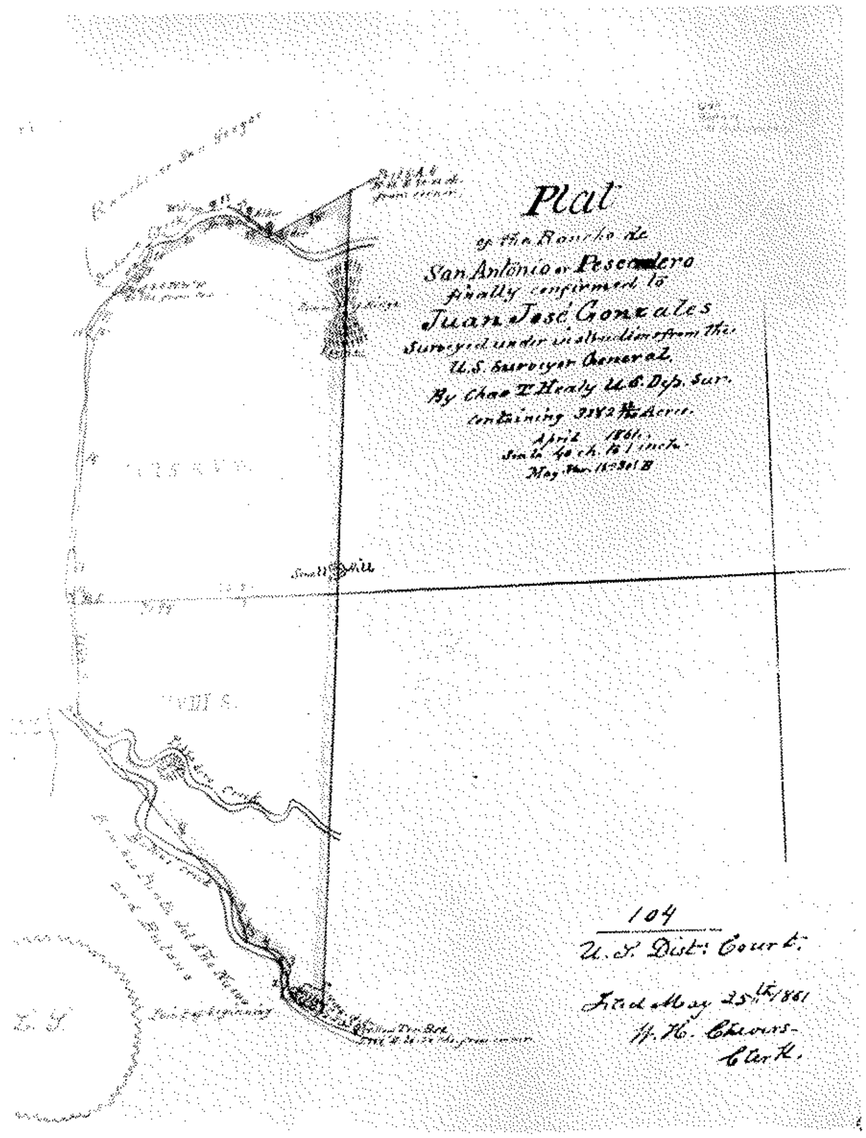


Figure 5. Plat of Rhancho de San Antonio or El Pescadero, Bancroft Library, U.C. Berkeley. The bottom left corner of the early map shows the confluence as well as Pescadero Creek bending around the north side of Round Hill.

place has never been the same. Soon other families arrived, including the Weeks, a family name enduring to this day. By the late 1850s, Pescadero comprised a village, with a store, post office, hotel and a school (Stanger, 1946).

The early settlers were farmers, dairymen, and lumbermen, the latter often living alongside their mills. Most settled during the late 1850s and early 1860s, after the first roads were built.

The first hotel, later known as the Swanton House, helped the economy and gradually transformed Pescadero into a resort community.

In the late 1860s, the Portugese from the Azores immigrated to the coastside to hunt whales. Pigeon Point was one of their primary settlement areas (Evans, 1874); later they moved to adjoining lands and became farmers and ranchers.

The population of the town in 1867 was estimated at 300 to 400, including people on adjoining farmlands south to Pigeon Point. In the late 1870s, a local newspaper located eleven dairies between Butano Creek and Point Ano Nuevo; most were owned by the Steele Brothers. Four dairies were also located north of Pescadero, all within two miles of the town (Stanger, 1946).

In the 1870s, Pescadero was described as a town in a small but fertile valley two miles from the ocean, a popular summer resort for San Franciscans, and a favorite headquarters of hunters and fishermen. The sportsmen were attracted by trout, salmon, ducks, small game and bear. Others came to hike the canyons and pick wild strawberries. Beautiful pebbles from Pebble Beach (2 miles south of Pescadero Beach) were very popular with the tourists. Mineral springs were available and there was a road via Woodside, Weeks, La Honda and San Gregorio with two stages daily (Alley, 1883).

Reporters from San Francisco visited and wrote about the wonderous attractions of the Pescadero region. It became known "as the Del Monte of its day," and held that position for more than a quarter of a century (Stanger, 1946).

Prosperity also rewarded those who worked the land. The Redwood City Times and Gazette (February 1, 1879) predicted that Pescadero might become a major flax producing region; it was the site of the first flax planting on the San Mateo coast in 1868 (Miller, 1971). In the late 1880s and 1890s, Pescadero was also famous for producing potatoes. Productive farms in the region were valued at fifty dollars an acre, but the potatoe lands near town were worth one hundred dollars or even more (Evans, 1874).

One of the oldest photographs of the town was taken in the late 1800s, and shows the old cemetery which is now covered by coastal scrub (Figure 6).

On December 27, 1890, the Half Moon Bay Advocate reported that Pescadero had a population of 300, with three churches, one school, two stores, two hotels, two public houses and two saloons.

Early 1900s. The hotel business declined at the turn of the century. The automobile enabled vacationers to reach other destinations easily. However, the promise of the Ocean Shore Railroad (a line that was to extend from San Francisco to Santa Cruz) rekindled the hope of tourism in Pescadero. By 1907, trains were running from San Francisco to Tunitas Creek (10 miles north of Pescadero) and from Santa Cruz north

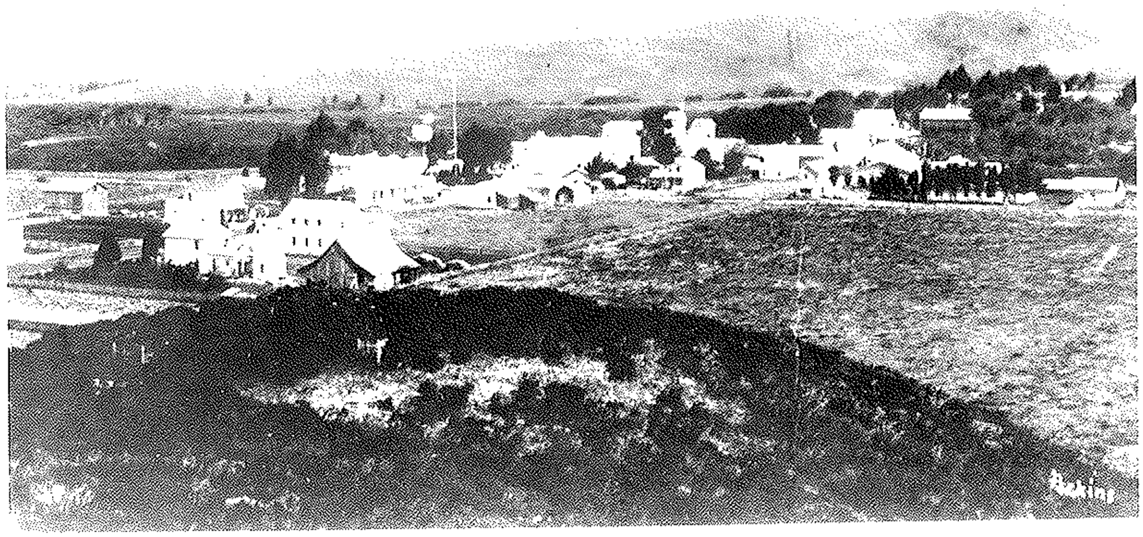


Figure 6. A pre-1890 photo of Pescadero. The view is northwest (photo from collection of Dorothy Regnery).

to Davenport. The 25 mile gap between these two points was made by an autocar connection.

Unfortunately, the railroad failed in 1920, due to financial problems. This represented the end of an era for Pescadero. Figure 7 is a photo of the town as it appeared in the late 1890s and early 1900s.

Some attribute the end of the economic boom to other forces. Dr. I. R. Goodspeed interviewed in 1921, said: "It was the failure of the lumber industry more than anything else. When I first went to Pescadero in 1860, there were 17 sawmills. There were flumes-lumber chutes down the mountains" (News Leader, San Mateo, California, 1921).

The economic decline was probably due to the arrival of the automobile, the declining lumber industry, and the failure of the Ocean Shore Railroad. In the late 1920s and 1930s, Pescadero assumed its present form and character of a modest coastal farming community. Figure 8 represents this period of time.

In 1938, Stanger wrote, "Pescadero, a village of about 500 inhabitants, is the principal town between Half Moon Bay and Santa Cruz. It is the business center of an agricultural and recreational area" (Stanger, 1938). In appearance the town has not changed very much. However, the original Anglo-American stock now constitutes less than half the population; and the other half is comprised of four more or less equal groups of Portugese, Italians, Mexicans and Japanese. Except for these cultural changes, and a few new buildings after fires, Pescadero has not changed much since the nineties (Stanger, 1946).

In 1979, Pescadero again had a population of approximately

Figure 7. Photo of Pescadero Town taken after 1895. View is to the north (photo from collection of Dorothy Regnery).

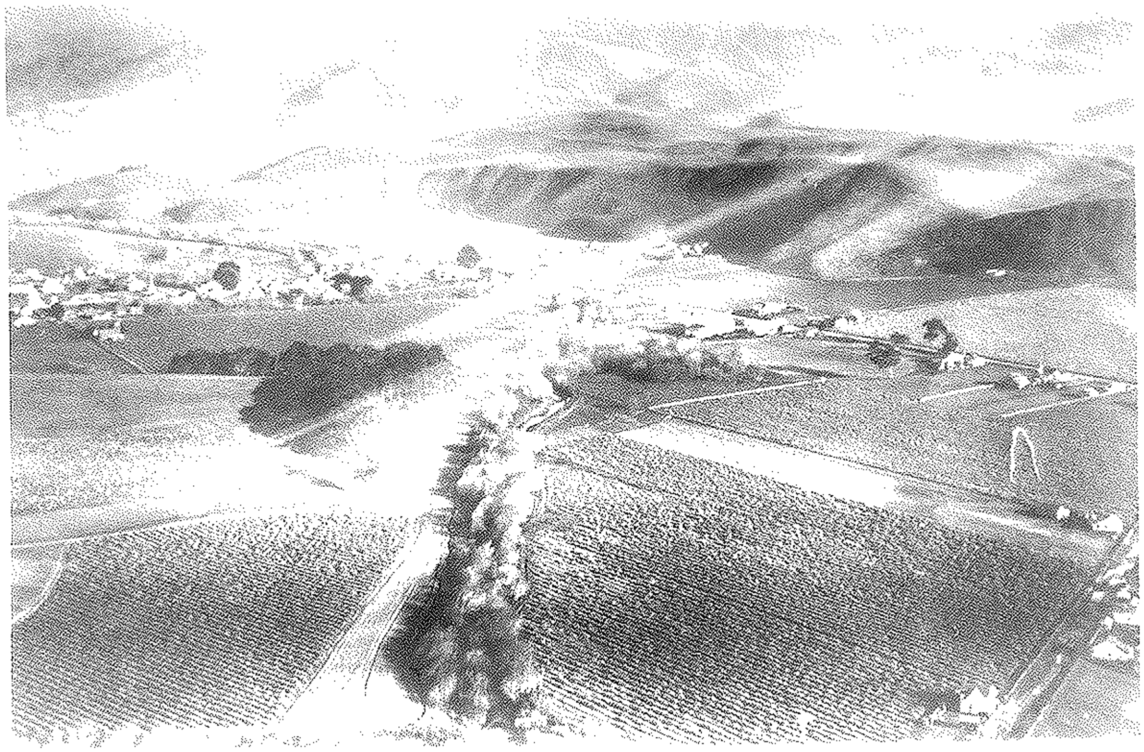


Figure 8. A photo of Pescadero taken from the air in the 1920s (photo from collection of Dorothy Regnery).

500 residents; it does not appear to be growing. Many of the residents are descendents of those who first arrived in the mid-1800s. The major economic activity centers on the production of specialty crops, such as brussel sprouts, artichokes and strawflowers. A limited amount of livestock grazing in the surrounding hills continues.

Charles Jones writing in A Separate Place, best describes the mood of the older residents of Pescadero. "They don't need change for the sake of change or progress in its witless gobbles. That is not the character of these people. They are not for or against change, they are simple indifferent to it" (Jones, 1974).

CHAPTER 2

THE PHYSICAL ENVIRONMENT

Climate

The Pescadero Marsh and drainage basin are characterized by a mild mediterranean-type climate. Indicative of this climate is an extended dry period from May through October. About 90 percent of the precipitation in the basin occurs from November through April. However, there is a wide range of annual precipitation within the basin (U.S. Army Corps of Engineers, 1969).

A 2,400 foot rise in elevation occurs from the mouth of Pescadero Creek to the rim of the drainage basin, a distance of 15.5 miles. This results in orographic precipitation, ranging from an annual mean of 20 inches near the coast to over 50 inches at the higher elevations. Snowfall is rare in the area and contributes insignificant measurable runoff (U.S. Army Corps of Engineers, 1969).

Seasonal temperatures show little variability from the annual mean of 54° near the coast. At the Half Moon Bay station about 15 miles north, a variation of less than 10 degrees Fahrenheit in average daily temperature is indicated for the winter and summer months (Soil Survey, San Mateo County, 1961). This moderate temperature range is determined by close proximity to the ocean.

At higher elevations, i.e., the La Honda area (about 9 miles northeast of the marsh), the summers tend to be warmer with many days having temperatures in the 80s. This warming trend with elevation increase (or a modified temperature inversion) is due to the inland movement of cool, saturated ocean air sliding beneath the warmer air. The warmer "land air" often acts as a lid on the cooler ocean air, and prevents it from rising to higher elevations (Gilliam, 1962).

The extended summer dry period and associated fogs are due primarily to a high pressure area, usually positioned about 1,000 miles off the California coast. This high pressure cell is known as the Pacific High. During the summer the intensity of the winds from the Pacific High increases. As the northwest winds blow southward along the coast, the force of these winds, coupled with the Coriolis force, tend to "push" surface waters away from the coast. To compensate for the loss of these surface waters, colder bottom waters tend to move upwards, "creating a continual fountain of upwelling" (Gilliam, 1962). These cooler upwelling waters cause the moist horizontally moving air to condense into fog. As the fog moves inland it collects on leaves and branches and some of the moisture eventually drops to the ground. Therefore, although the late spring and summer months are relatively free of rainfall, the sky is often overcast and the ground is frequently damp.

Terrain

Pescadero Marsh consists of approximately 500 acres of wetland, centered around the confluence of Pescadero and Butano creeks. These creeks join less than one-half mile from the coast. This is a land of sand, mud and silt, held in place by a dense growth of coastal halophytes (salt tolerant plants). In recent years artificial levees have been constructed; they now form a network of raised earth throughout the marsh. The physical and biological conditions in the marsh fluctuate depending on the runoff and the extent of tidal interaction. Salt intrusion in the marsh has not yet been fully documented (See Chapter III). Pescadero Marsh is a brackish water marsh as well as a fresh-water marsh, as indicated by the distribution of flora and fauna.

The marsh extends from a conspicuous sand spit on its westward, seaward margin, to the southeast for nearly one mile. It averages approximately one-third of a mile in width (Figures 2 and 3). At its northern edge, the marsh is bordered by Eucalyptus groves and coastal scrub, which mark the beginning of a series of low rolling hills. Before the construction of levees, the marsh probably appeared relatively flat and varied little from sea level.

Agricultural lands border most of the southern margins of the marsh. Fields used for livestock and crops create the major boundary between the marsh and the town of Pescadero.

The town of Pescadero, approximately one mile east of the marsh, is situated on a broad alluvial flood plain that is being cultivated; coastal hills mark the edge of this flood plain. The topography of the upper Pescadero and Butano basins is steep and the streams are deeply entrenched in V-shaped valleys. The drainage system has a pronounced rectangular or trellis shaped pattern, and the major ridges have a northwest orientation.

Eastward from the coast, the topography changes dramatically with increase in elevation. Marine terraces give way to sand dunes, wetlands and flood plains, which join coastal hills and the steep-walled redwood canyons of the interior.

Drainage

The Butano and Pescadero creeks provide the major source of water for the Marsh system. Both are perennial streams, although there is very little flow during extremely dry years. Because they originate in upland areas of high rainfall, they carry a large volume of runoff in the winter and spring (Soil Survey, San Mateo County, 1961).

Between San Francisco and Santa Cruz counties, approximately 276 square miles drain into the Pacific Ocean. Of the various watersheds, the largest is the Pescadero Drainage Basin (including the Butano system), which drains an area of 64 square miles. The two streams have gradients ranging from 1000 feet per mile in the upper portions of the basin to 15 feet per mile in the lower portions. Eventually they wind their way westward through the marsh toward the sea (U.S. Army Corps of Engineers, 1969).

In recent years, however, a sand bar has blocked the mouth of the creek most of the time. Thus, during periods of heavy or prolonged rainfall, the waters tend to flood the adjacent croplands; and the marsh water regime has been altered. Yet the flooding of the Pescadero and Butano creeks has been a natural phenomenon, even without the sand bar. Records from the Pescadero gauge indicate that peak discharges have produced damage on nine occasions since the gauge was installed in 1951. The most severe flood occured during 1955, with a maximum discharge of

9,420 cfs (cubic feet per second) recorded on 23 December, and with a half million dollars of damage to agriculture, commercial, and public works projects. Prior to 1951, discharges of major significance probably occured during February 1894, January 1909, and January 1911, January 1916, February 1940 and January 1943 (U.S. Army Corps of Engineers, 1969).

The average annual streamflow of Pescadero Creek between 1951 and 1976 was 29,670 acre feet. A low of 2,970 acre feet occured in 1975-76, and a high of 74,790 acre feet in 1957-58. Ninety percent of the total annual flow occurs during the winter months with peak discharge in December and January, with the largest percentage of precipitation originating on the higher, wooded elevations. Even though the densely vegetated understory and the thick forest litter layer protect the soil and maintain high infiltration capacities, streamflow responds rapidly to precipitation. This indicates that a considerable volume of water reaches the main channel through interflow, the rapid subsurface movement of water (Roberts, J.A. Association, 1975).

Channels in the basin are often steep, nearly vertical in some places. The steepness of the slope is probably attributable to a continuing history of undercutting followed by mass failure (downward movement of rock debris). These features, together with a strong meander pattern, may indicate that rejuvenation (newly accelerated erosion) has taken place in the geologic past, resulting from the lowering of base level or from local uplifting.

Geology

This section includes Geology and Geologic history; it contains a summary of two recent investigations of the study area and surrounding region. Rocks in the region date back to pre-Cretaceous times (about 100 million years ago).

The more recent geologic history of Pescadero Marsh (2 million years until present) is contained in Chapter Four and restated in the summary in Chapter Five.

Pescadero Marsh lies in the southeastern corner of the San Gregorio Quadrangle. The Geology of this region has been studied and mapped in recent times by Hall, Brooks and Jones (Geology of Pescadero-Ano Nuevo Area, 1953), and by Cummings, Touring and Brabb (Geology of the Northern Santa Cruz Mountains, California, 1962). A Geologic map of the study area has been included at the end of this section (Figure 9).

The oldest exposed rocks are found about 10 miles south of Pescadero Creek on Ben Lomand Mountain; roof pendants of Pre-Cretaceous meta-sediments intruded by quartz diorite. However, the oldest rocks in the vicinity of the marsh are the late Cretaceous sediments of the Pigeon Point formation. This formation, consisting of sandstone and siltstone with some shale and conglomerate, extends from Pescadero Beach south along the coast for 11 miles. This formation is overlain unconformably at Pescadero Beach by the Mindego formation, which is locally Oligocene in age, and the Purisima Pliocene formation 2 miles southeast of Pescadero Beach (Cummings, Touring and Brabb, 1962).

The regions Tertiary rocks are the most extensive and they include the Butano Sandstone, Vaquero formation, Monterey Shale, Purisima formation and those designated as igneous.

The Butano sandstone makes up the northwest trending Butano ridge (4 miles east of the town of Pescadero). This sandstone is interbedded with silty sandstone and shale. Although there are variations in lithology, most of the formation is light gray or very pale orange, moderately sorted, medium grained sandstone, in beds from 1 to 10 feet thick (Cummings, Touring and Brabb, 1962).

The Vaquero Sandstone, distributed over a large part of the northern Santa Cruz Mountains, is absent over much of the San Gregorio Quadrangle. Near the mouth of Pescadero Creek the Vaquero formation is overlain unconformably by a lava flow. The Vaquero formation consists of a coarse-grained, poorly sorted, light gray sandstone. The grains are subrounded and are cemented by calcite, magnetite and muscovite (Hall, Brooks and Jones, 1953).

The Monterey Shale is located some distance from the marsh. The rocks of this formation are found east of the San Gregorio Fault, as well as in the vicinity of Ano Nuevo Point. This formation consists of approximately 3,900 feet of "porcelaneous, siliceous and ditomaceous light gray brown to dark gray, thin-bedded shale" (Hall, Brooks and Jones, 1953).

The Purisima formation is made up of approximately 9,300 feet of sandstone and shale. Hall (1953) divides the formation into three members: lower sandstone, middle shale and upper sandstone. The lower member is found along Pescadero Creek and and in the vicinity of La Honda. It consists of approximately 4,200 feet of medium-grained, soft, gray and brown sandstone, which contains thin beds of gray to brown, spheroidally weathered siltstone and claystone. The middle shale member of the Purisima formation is approximately 3,700 feet thick and consists of "diatomaeceous and agrillaceous, gray-white, gray-black, black and brown, occasionally opaline, well indurated to soft shales" (Hall, Brooks and Jones, 1953). The upper member consists of about 1,300 feet of sandstone occasionally interstratified with a clay shale.

Locally the Purisima formation extends west of the town of Pescadero to the coast, and east and northeast to Jones Gulch (approximately 8 miles). The boundaries of the Purisima formation are the Pacific Ocean on the west, east of a line drawn from La Honda to Jones Gulch on the east, and north of an eastward line drawn from San Gregorio to La Honda at the northern boundary.

Quaternary rocks in the Pescadero area are made up of marine and river deposits as well as the most recent alluvium. Terrace deposits are found along the coast from San Gregorio to Ano Nuevo, and on some low hills to the east at an elevation of about 600 feet. The marine terraces are presumed to be Pliocene (Cummings, Touring and Brabb, 1962).

Stream terraces are found along Pescadero Creek. Lower beds are composed of gravel and sands chiefly from the Mindego formation. The upper beds are composed of fine silt which grades upwards into recent alluvium.

The igneous rocks are probably Cretaceous in age and are exposed in road cuts along Pescadero Road, near the south edge of the marsh. They consist of spilitic basalt overlain by soda rhyolite. The relationship of these rocks to the surrounding area is not known. "It cannot be safely stated whether these rocks are in the form of lava flows, or intrusive dikes or sills" (Hall, Brooks and Jones, 1953).

The most prominent structural features within the drainage basin include the Pescadero syncline on the north side of Pescadero Creek; the Butano anticline, forming Butano Ridge south of the creek; and the Butano Fault, separating the two folds. These two features traverse the general trend of the drainage basin at a slight angle and can be traced for several miles to the northwest and southwest (U.S. Army Corps of Engineers, 1969).

Geologic History

During the Cretaceous (100 million years ago), the area had been submerged by the sea. In Paleocene times (60 million years ago), there was a general withdrawal of the sea and a period of non-deposition, followed by the sea re-establishing itself over the area that had been submerged in the Cretaceous period. Around the Eocene (40 million years ago) and the Oligocene (30 million years ago), folding occured, followed by a time of submergence and the inland spread of lower Miocene seas (25 million years ago). The lower Miocene time was marked by igneous activity which produced the lava flows and pyroclastic deposits found west of Pescadero (Hall, Brooks and Jones, 1953).

During the middle and upper Miocene, the Monterey formation (siliceous shales) was deposited, representing the deeper water conditions of these periods. These conditions were repeated during the lower Pliocene (10 million years ago), which are represented by the middle Purisima shales.

After the late Miocene, the Purisima formation was deposited--a time of emergence, erosion, and a period of submergence. "Following the deposition of the Purisima formation, parts of the present landscape were probably established, subsequent to displacement along faults" (Hall, Brooks and Jones, 1953).

Stream rejuvenation, recurrent seismic activity, and warping of even the youngest marine terraces along the coast, indicate that crustal forces in this region are still active (U.S. Army Corps of Engineers, 1962).

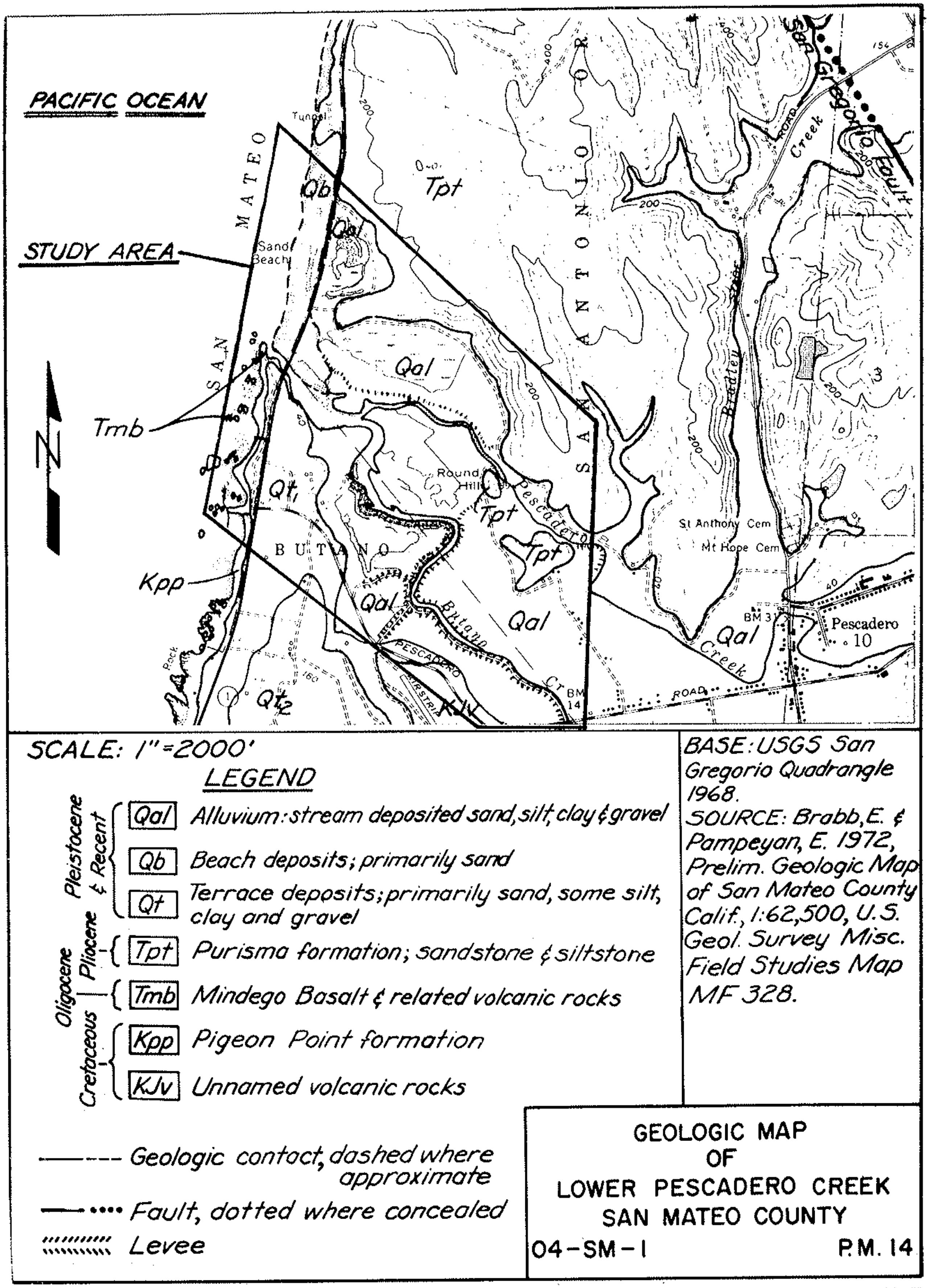


Figure 9. Geologic Map of Study Area (modified version of the map used by: Hayes, Walsh and Casinelli, 1977).

CHAPTER 3

PESCADERO MARSH FLORA AND FAUNA

Pescadero Marsh: A Physical Definition

Coastal bodies of water can be defined by their geomorphological characteristics as well as by circulation patterns. Estuaries have been classified according to the type and extent of mixing that occurs (Pritchard and Carter, 1971). However, the most important distinction concerning this marsh is whether it is properly termed an estuary or coastal lagoon.

Using Pritchard's definition (1967), "an estuary is a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water from land drainage."

Pescadero Marsh is a coastal body of water, semi-enclosed, in which sea water has been measurably diluted with fresh water from land drainage. However, if we consider a "free connection with the open sea" to mean a continuous phenomena, then Pescadero Marsh does not satisfy the definition. Estuarine circulation does not exist within the lagoon and marsh area much of the year. A sand bar at the mouth of the creek prohibits the free mixing of fluvial and littoral waters.

Under present conditions, it is probably best to state that Pescadero Marsh is located at the fringe of a coastal lagoon. A coastal lagoon is "a body of shallow water, particularly one possessing a restricted connection with the sea" (Trowbridge, 1962).

Yet it is impossible to reduce all coastal wetlands to a single characteristic. Pescadero Marsh is an individual ecosystem with its own interesting identity reflecting unique local conditions.

With the recent construction of levees and roads, it is no longer a textbook example of a coastal lagoon. Perhaps we are seeing a transition from estuary to lagoon, more recently modified by the addition of ditches, ponds, levees and other man-made features. In Chapter Four, I offer evidence that the above evolutionary sequence is correct.

However, tidal activity in the channels surrounding Pescadero Marsh continues, although its regularity has not yet been monitored. I found that littoral debris in Butano Creek had been transported nearly one mile upstream.

The summer of 1978 was a good period for testing the salinity of the waters above the confluence, for a free sea connection existed until late August. I found a salt wedge had developed upstream from the confluence, and I noted the changes in vegetation due to these salinity changes. Further recorded was the existence of pools of denser saline water along portions of Butano Creek, possibly resulting in waters having low dissolved oxygen. Additional testing is required.

Figure 10 on the following page indicates the salinity gradient as it was recorded during August 1978, using a Kahlsico hydrometer. Although the creek was relatively low, I encountered several species from the littoral zone nearly one mile upstream; these included Postelsia palmaeformis (Sea palm), Egregia menziesii (Feather kelp) and Nereoystis luetkeana (Bull kelp). Also noted was the bottom sediment, littered with fragments of clams and crustacea, species not presently living in the lagoon or marsh area.

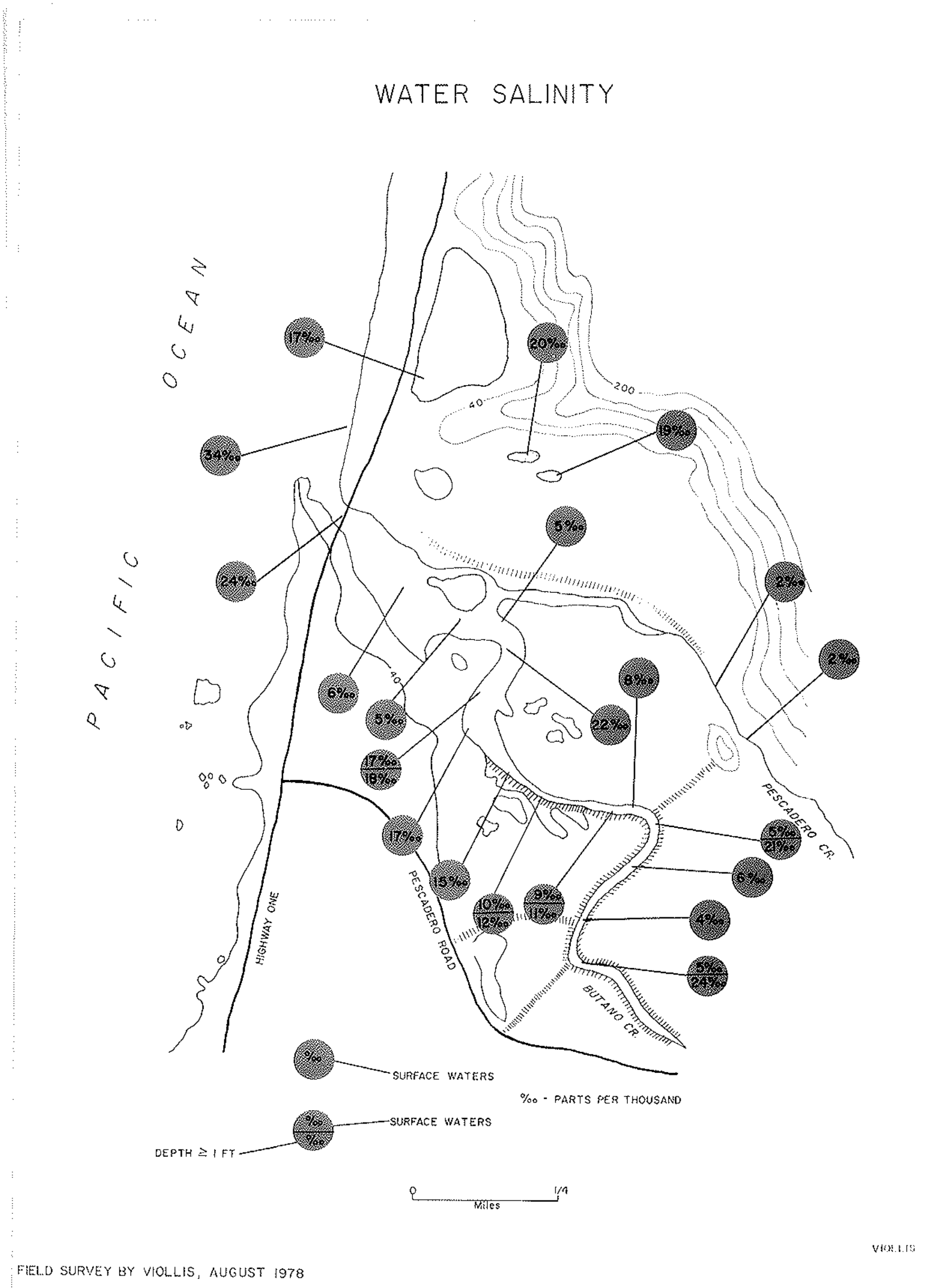


Figure 10. Water Salinity.

Pescadero Marsh Vegetation

The physiognomic and floristic nature of the vegetation at Pescadero Marsh is extremely varied. The vegetation has been divided into six types (Figure 11). These include: (1) Beach and Dune; (2) Salt Marsh; (3) Freshwater Marsh; (4) Coastal Scrub; (5) Eucalyptus Grove; and (6) Agricultural. While the first three are synonomous with Munz (1968), the latter are not. Within Coastal Scrub are included dominants from two distinct plant communities which Munz (1968) has named Northern Coastal Scrub and Coastal Sage Scrub. The last two types, Eucalyptus Grove and Agricultural, are included because they constitute a major portion of the cover in and around Pescadero Marsh.

Although both Riparian and Ruderal vegetation are considered, they were not included in this vegetation map. Ruderal vegetation occupies disturbed habitats and "waste places," and is closely related to human activities (Frenkel, 1970). The words ruderal and disturbed will hereafter be used interchangeably.

Pescadero Marsh has a series of levees, some trails, a highway, and a road on its western and southern edges. The vegetation of these disturbed sites is similar; its location on the map corresponds to the line symbols representing roads and levees. A symbol for trails has not been included since most of the trails are on the levees, the major exception being the trail around the north pond.

The only significant stand of riparian vegetation within the marsh is along Pescadero Creek in the vicinity of Round Hill. This vegetation type is well developed outside the marsh complex in the lower Pescadero and Butano Valleys. A symbol for riparian vegetation was not included in the map.

A map showing the locations of the vegetation photographs (Figure 12)

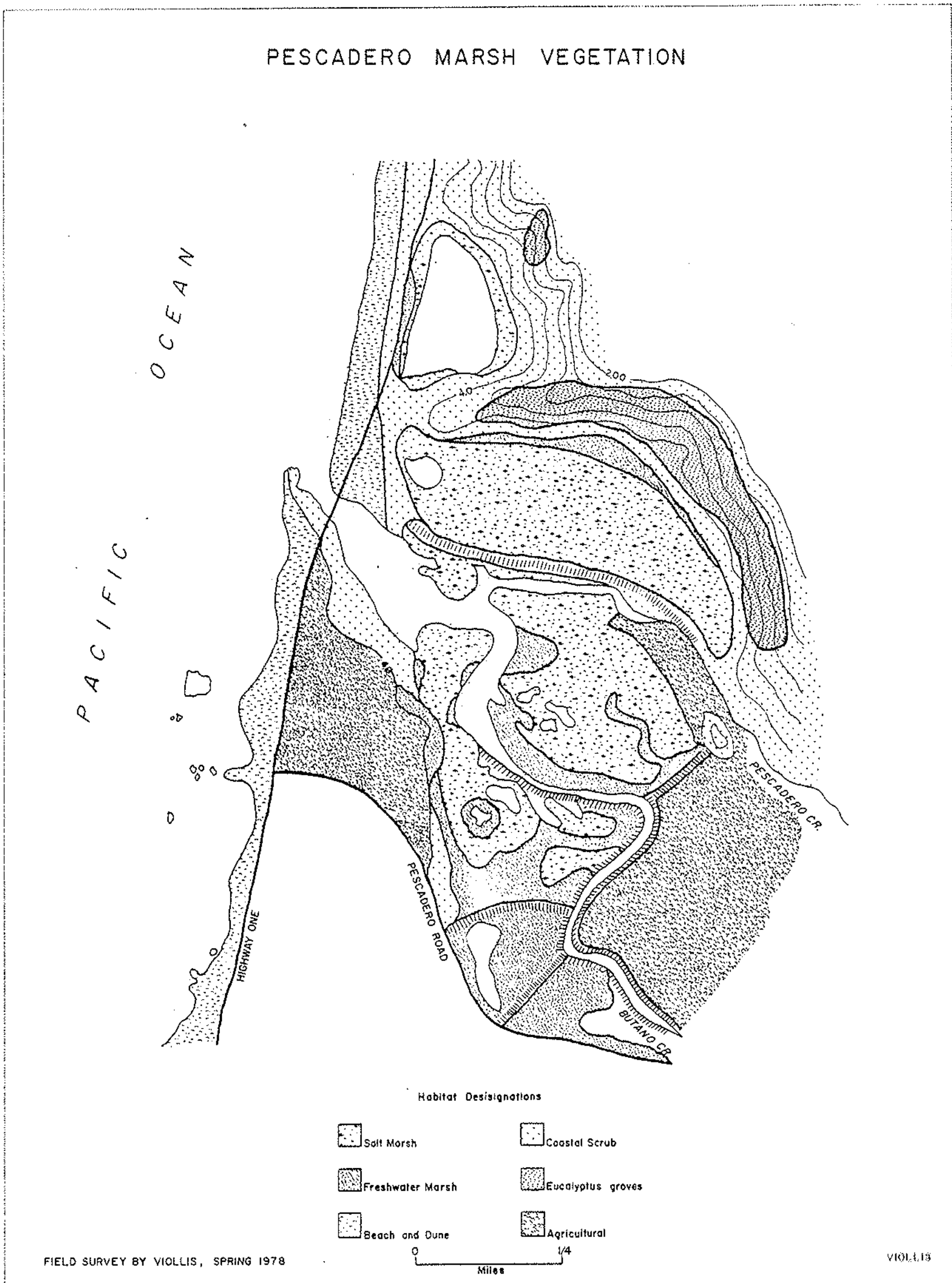


Figure 11. Pescadero Marsh Vegetation.

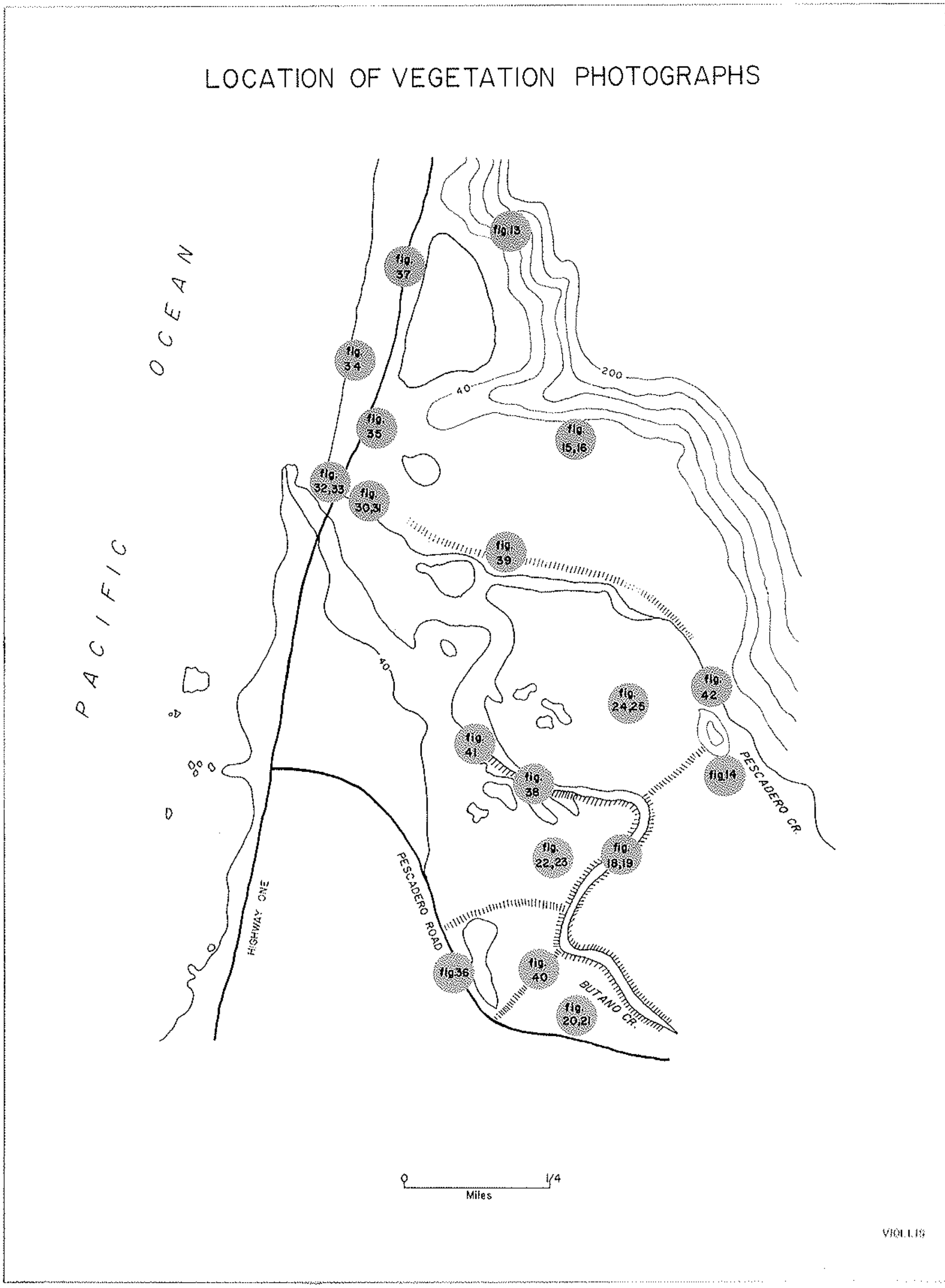


Figure 12. Location of Vegetation Photographs.

will aid those unfamiliar with the study area.

The various vegetation types will be discussed in terms of distribution, historical development, and ecological significance.

For plant identification I have used several sources. Many of the plants were identified as part of field study in Plant Taxonomy during the spring of 1978. I have used Philip Munz's A California Flora (1968), as well as Herbert Mason's A Flora of Marshes of California (1957). A Flora of Pescadero Marsh (1975), by William Anderson and Randy Morgan, has also been helpful.

Reconstruction of Vegetation

The vegetation was somewhat different when humans first arrived at the confluence of Pescadero and Butano Creeks. When the coast people first utilized the natural resources of Pescadero Marsh may never be known. However, there is little doubt that they did play a role in modifying the natural vegetation of the surrounding region.

To increase the yield and frequency of food crops, the Indians often burned their grasslands, creating their most significant impact to the landscape (Miller, 1971). Father Crespi, while traveling north in the vicinity of Arroyo De Los Frijoles and Pescadero Creek, noted on October 24, 1769: "We set out at half-past eight with two heathen of this village who came to guide us, taking a northerly direction, in sight of the sea, over broad hills of good land, but all burned over and despoiled of trees" (Bolton, 1926).

When the Spanish first arrived, probably the only disturbed plant communities were the burned over lands mentioned in these early accounts. Exotic grasses and weeds were introduced into the valley of the Pescadero in the early 1800s, when Santa Cruz Mission range lands extended north to Half Moon Bay. Seeds transported with herds of livestock, colonized disturbed sites, such as Indian burns, trails, overgrazed lands and other cultural changes. Many of the new species spread from Monterey, the center of Spanish activity in the early days--including wild oat, mustard, wild radish, fox-tail and bur clover (Gordon, 1974). Today these plants are numerous on levees, along roadsides, and in abandoned fields surrounding Pescadero Marsh. When the first American settlers arrived, many of these exotic species were well established. According to Eli Moore, among the earliest of the settlers, wild oats grew to a height that reached his horse's back (Stanger, 1946).

Coastal Scrub

The hills surrounding the north pond and those that border the larger groves of eucalyptus are covered with a patchwork of coastal scrub and grasses, with intermittent erosion gullies of bare sandstone (Figure 13). In some places the erosion is occurring at such a rapid rate that the area is completely devoid of vegetation. Several factors may have been responsible for the present scarred landscape. Burcham (1957) notes that severe droughts were frequent in California during the 1800s. The drought of 1828-1830 was so severe that no rainfall occurred in the coastal area south of San Francisco for 22 months. This was also the period when the grazing of mission herds extended from Santa Cruz north to Half Moon Bay. A traveler describing the coast south of San Francisco in 1827 remarked: "A fine verdue clothed the plains and hills where we continually saw immense herds of cattle, sheep and horses. Those of Santa Cruz meet the less numerous ones of San Francisco so that this long stretch of eighteen leagues is nothing but one continuous pasture" (Burcham, 1957).

The droughts, together with overgrazing, followed by a few years of heavy rainfall in the late 1800s, could have been partially responsible for the erosional features on the present landscape. Poor agricultural practices associated with flax production have also been cited (written communication, Raymond Pestrong, May 1979).

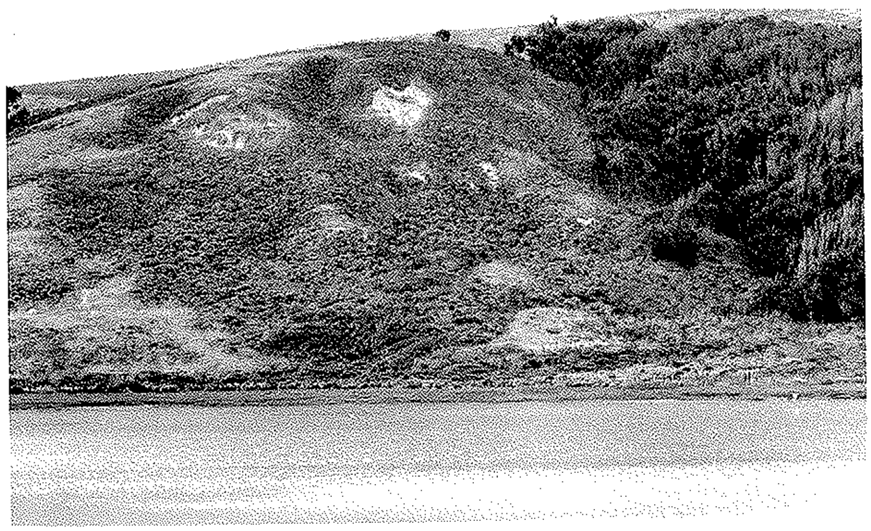


Figure 13. Photo taken in 1978 of hills bordering the north end of the north pond.

Prior to the introduction of cattle and other range animals, the coastal hills in this area were probably covered with native grasses. Presently the dominant coastal scrub species is Baccharis pilolaris

(Coyote Brush); however, recent investigations indicate that it is actually invading grasslands as a consequence of the reduction in wild-fires and the elimination of grazing (McBride and Heady, 1968). According to Dr. Burton L. Gordon of San Francisco State University, coffee berry and Pacific blackberry may be the potential natural vegetation of the coastal hills. Accounts from Portola's expedition in 1769 give support to the abundance of blackberry in the area. Father Crespi, while in the immediate vicinity of Pescadero, commented: "It is a pleasure to see the great number of blackberries in this place, so thick that they prevent us from walking" (Bolton, 1926). Today the blackberry near Pescadero Marsh is limited to the levees and roadsides.

The largest patches of coastal scrub are found on the hills that surround the northeastern corner of the marsh, above the trail which winds along the north pond, and above the large growth of eucalpytus trees. The only other portion of the marsh with this type of vegetation cover is Round Hill.

Baccharis pilolaris, the dominant, has growth forms which range from a low mat-like cover one foot high at its seaward distribution, to nearly six feet tall in more protected and inland habitats, away from the wind and where there is abundant water. *Artemisia* sp. (Sagebrush) and *Mimulus aurantiacus* (Sticky Monkey Flower) both grow on the higher slopes above the trail around the north pond. *Rhus diversilobia* (Poison-Oak), while found in most areas surrounding the marsh, reaches its greatest density atop Round Hill (Figure 14), with *Baccharis pilolaris* being the dominant and *Lupinus* sp. (Lupine) and *Mimulus aurantiacus* being the sub-dominants.

Figure 14. Artichoke field with Round Hill in the background. View is looking northwest (photo taken in 1978).

In more open grassy areas, a number of herbaceous plants flower in mid-spring, including: Oenothera ovata (Golden Eggs), Sidalcea malvaeflora (Checkerbloom), Castilleja sp. (Paintbrush), Eshscholtzia californica (California Poppy) and Ranunculus californicus var. cuneatus (California Buttercup).

Round Hill is isolated from the rest of the marsh by its abrupt rise in elevation, an eighty foot high sandstone hill, fenced off from grazing livestock. While Baccharis is still the dominant plant on the hill, Rhus diversilobia is very near being a co-dominant, which may indicate a successional change.

Eucalyptus Grove

A vivid feature of Pescadero Marsh is the large grove of eucalyptus that lines the north side of the marsh and is easily identified on the air photos. Eucalyptus Globulus (Blue Gum) is found growing here with a dense scrub-like undergrowth. The blue gum was brought to San Jose in 1858, and soon after was widely planted for hardwood (Gordon, 1974). A close look at Figure 6 may provide an approximate early date for the groves in the Pescadero area; in the upper right hand corner is faint evidence that a grove was established prior to 1890. Most of the larger groves in the area share the same degree of development, suggesting that they were planted during the same period.

Malaria was a major cause of illness in California in the latter half of the 19th century. Some members of the medical profession believed that malaria was caused by "miasma" or "bad air." Eucalyptus, with its leaves "introducing pungnet, antiseptic, volatile oils into the air, was the fever destroying tree" (Gordon, 1974). Of course we do not know exactly why the trees were planted around Pescadero Marsh, but marshes in those early days were suspected as disease sources.

Figures 15 and 16 show the same stand of eucalyptus over a period of forty years. Also notice the changes in vegetation of the dunes which line Pescadero Creek.

Marsh Vegetation

The very first reference to a marsh in the vicinity of Pescadero was that recorded by Father Palou on December 8th, 1774, while traveling

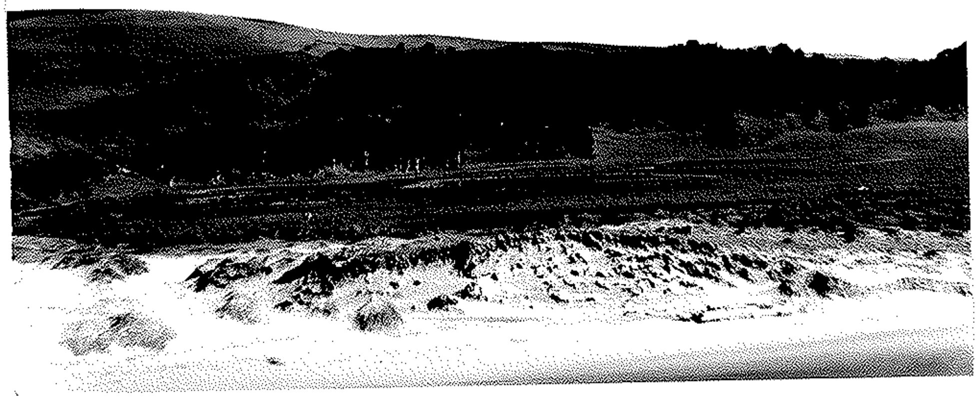


Figure 15. Eucalyptus grove as it appeared to Dr. Robert T. Orr in 1938. View is to the north.

Figure 16. Eucalyptus grove today (1978). The grove is obviously more luxuriant at the present time. The vegetation on the dunes as well as the scrub growth above the grove has changed dramatically.

south between Pescadero and Arroyo De Los Frijoles:

> two large arroyos distant from each other about a league, both with large volumes of running water coursing through a heavy growth of willows, sycamores and live oaks. At both it was necessary to dismount in order to cross. Besides the two large arroyos, it has other fair sized ones, with whose water with a little labor it would be possible to irrigate the abundant land for raising crops which those valleys have. We likewise encountered in them some lakes with plentiful water and large tule marshes. There is an abundance of firewood and also of timber for building, especially red cedar, of which there are groves of dense growth. (Bolton, 1930)

Field notes of government land surveys now kept at the Bureau of Land Management in Sacramento make reference to the marshes in 1857. Surveyor J. Kellesberger mentions a "salt marsh" in 1857, while another survey in 1862 puts the "salt marsh" as being the northern boundary of Rancho Butano.

However, the relationship between salt marsh and freshwater marsh (prior to levees and roads) is best displayed in a 1925 Peninsula Farms Survay Map (Figure 17). Although the map is generalized, it does indicate the major areal distribution of these two plant types as they were later described by Orr in 1939.

Orr noted that it was the eastern portion of the marsh that had extensive tall stands of vegetation, i.e., _Typha_ (Cattail) and _Scirpus_ (Tule and Bulrush):

> Here occur a number of small ponds which are rather inaccessible, from a human standpoint, but due to the protection they are afforded by the surrounding dense stands of cattails and bulrushes they prove especially attractive to ducks, coots, bitterns and other species. The western portion of the marsh contains considerably less cattail and bulrush growth than the eastern part and is mostly covered with pickleweed and its associates. (Orr, 1942)

He also mentions that Pescadero and Butano Creeks, as well as a number of sloughs, are lined for a good portion of their length with tall marsh growth.

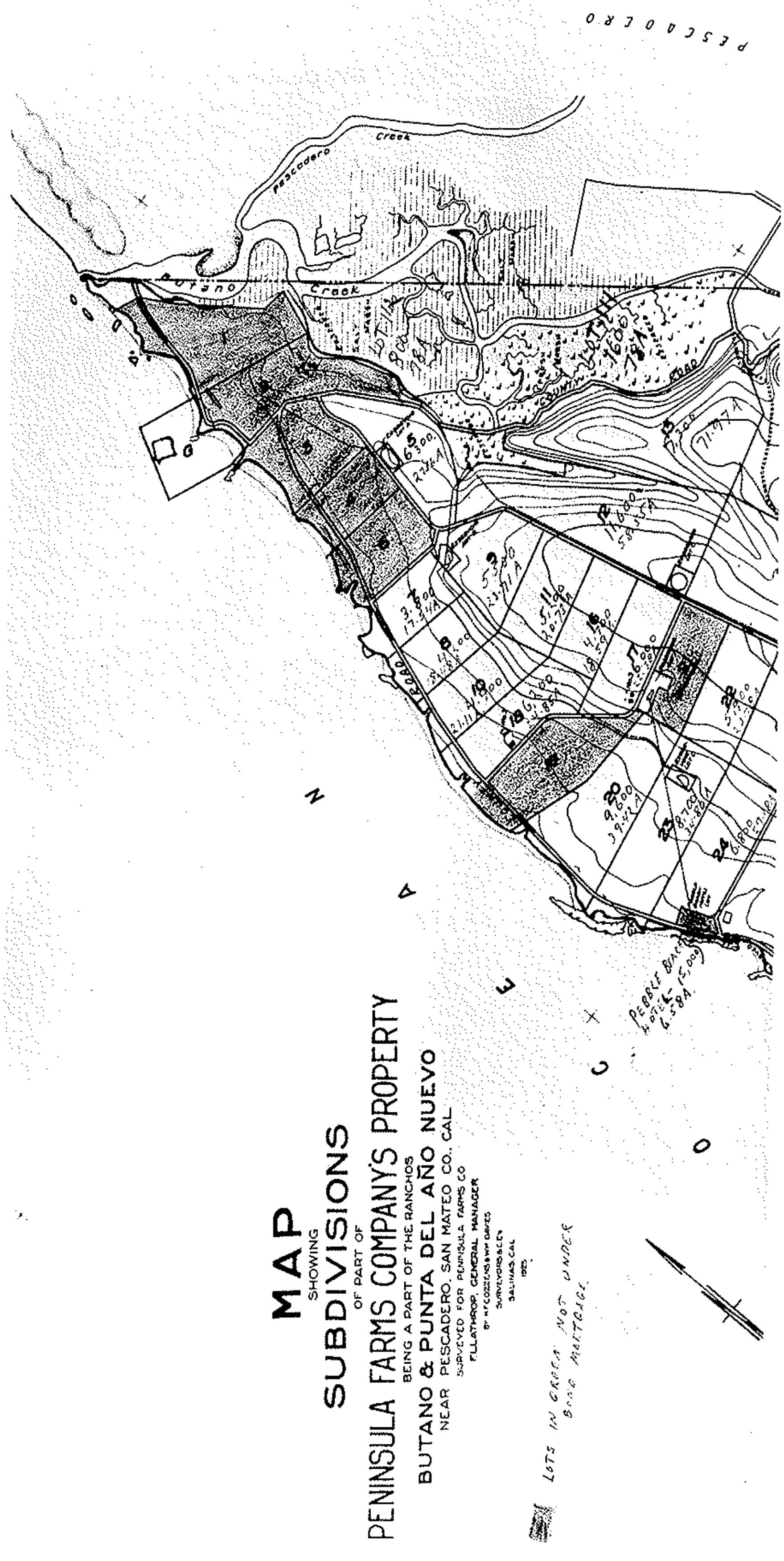


Figure 17. Map obtained from the California Historical Society, San Francisco.

Orr lists a few of the plants he found: Typha latifolia (Broad-leaved Cattail), Scirpus validus (Great Bulrush), Salicornia ambigua (Pickleweed), Distichlis spicata (Salt Grass), Atriplex hastata (Fat Hen), Frankenia grandifolia (Alkali Heath), Potentilla anserina (Silverweed), and Grindelia cunefolia (Gum Plant). I will review the present status of these and other marsh plants.

The present distribution of marsh vegetation is extremely interesting. Ponds merge with drainage channels, freshwater marsh plants meet riparian communities, brackish conditions extend throughout most of the marsh (but very seasonally), and salt marsh species grow alongside those that are generally considered freshwater plants.

This is the nature of the distribution of the Pescadero Marsh plants. Distribution is primarily natural and controlled by elevation, relative permanence of water, tolerance to salinity, and competition for space. However, some plants have a wide range of tolerances; the common cattail, Typha latifolia, "occurs along salt and alkaline marshes near the coast and in the Central Valley, and in fresh water from sea level to middle altitudes in the Sierra Nevada" (Mason, 1957). Most of such wide ranging species are composed of genetically distinct ecological races (Mason, 1957). Other species in the marsh also seem to possess a wide range of tolerances.

Of the vegetation types listed on the map, the freshwater and salt marsh plants have undergone the most recent changes in distribution as a consequence of human-related activities. Prior to the construction of a series of ditches and levees, the migration of freshwater species into pickleweed regions was controlled by drainage channels. Since the natural waterways have been "cut off," a redistribution of some species has taken place. Leveed lands have been flooded, drained and cultivated. Evaporation of freshwater areas has led to the intrusion of salt tolerant species, including salt grass and pickleweed.

Marsh vegetation will be discussed under two headings: freshwater marsh and salt marsh. The freshwater marsh is that part of the marsh which is dominated by *Scirpus* and *Typha* and includes their associates. The salt marsh at Pescadero is dominated by *Salicornia* and *Distichlis* and contains their respective associates.

Freshwater Marsh

Today the dominant freshwater vegetation is *Scirpus*, with smaller clusters of *Typha*. *Scirpus robustus* (Alkali Bulrush) is by far the most widespread species and possesses the greatest range of tolerance to salinity and submergence. *Scirpus californicus* (California Tule) is also abundant; however, it is limited to lesser saline conditions and is common along freshwater ditches.

The southeastern corner of the marsh has undergone the greatest change in vegetation due to the recent construction of levees. Because of this, the plant cover is a patchwork of non-uniform clumps of *Scirpus* and *Salicornia virginica*. This patchiness is easily seen on the vegetation map (Figure 11). A look at three sets of photos taken forty years apart, provides a clear picture of the changes that have taken place (Figures 18 through 23).

Incidentally, the photos also record the invasion of *Baccharis* that has taken place in the hills north of the marsh (Figures 18 and 19).

Figure 18. Butano Creek with Round Hill in the background (photo taken by Dr. Robert T. Orr in 1938).

Figure 19. Photo taken of Butano Creek in 1978 showing changes in vegetation along the streamsides and upon the hills. The size of the channel has been reduced with the spread of plant growth. Notice the invasion of *Baccharis* on the distant hills.

Figure 20. Photo taken from southeastern corner of the marsh in 1938 by Dr. Robert T. Orr.

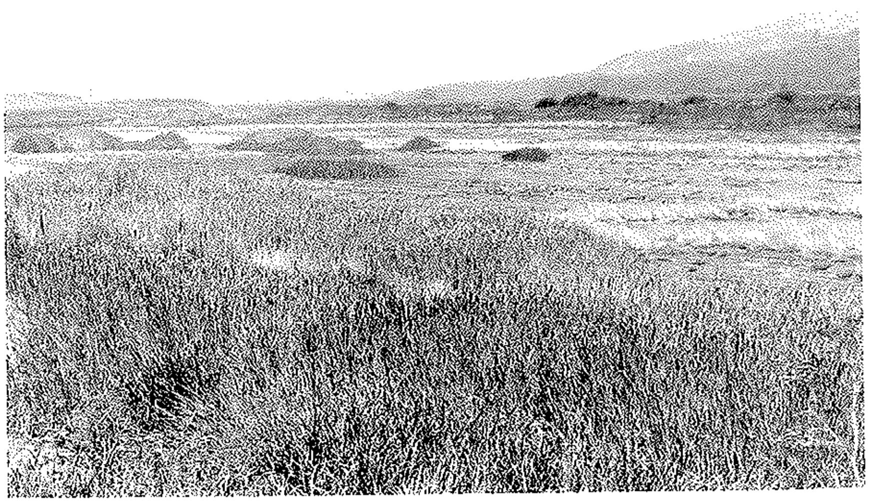


Figure 21. A 1978 photo of the southeastern section of the marsh, showing vegetation changes as a result of levee construction. Also evident in this photo are the remnants of an old agricultural field.

Figure 22. Freshwater marsh vegetation as seen by Dr. Robert T. Orr in 1938.

Figure 23. This photo taken in 1978 shows major changes in the pattern of marsh vegetation over forty years. Notice how the once uniform growth of freshwater marsh vegetation (See above photo) has been transformed into isolated clumps of both freshwater and salt marsh plants.

The photos taken by Orr in 1938 show the eastern and southeastern section of the marsh prior to the construction of levees; comparative photos were taken during the summer of 1978. During the winter and spring of 1978, runoff was high and water in the marsh was abundant until late spring. Freshwater marsh vegetation reflects yearly water conditions in the marsh, and during years of low runoff, plant growth is not as dense as that of wet years.

As suggested, the levees have produced a number of physical changes that have led to a strange assemblage in plant association (Figure 23). In these modified portions of the marsh, deep pools are inhabited by Scirpus californicus and S. robustus, with Salicornia virginica growing on dry land. The manipulation of the earth-levees (either to flood or drain marshland) continues today. However, the duck clubs are now gone and planting of crops in the southeastern corner of the marsh occurs rarely.

Freshwater marsh vegetation has been reduced due to levee and road construction. What effects this has had on bird life is uncertain. The birds of Pescadero Marsh will be discussed in detail in the latter half of this chapter.

The growth of algae and the decay of organic debris becomes more evident in late summer. The water in the pools, ditches, and upper channel is turbid, shows little movement, and salinity increases with increased evaporation.

Salt Marsh

The salt marsh, like the freshwater marsh, was more extensive prior to the construction of levees and roads. The dominant plant of this salt marsh is Salicornia virginica. Associated with it is: Distichlis spicata, Jaumea carnosa (Fleshy Jaumea), Atriplex patula, Grindelia latifolia and Frankenia grandifolia.

If Pescadero Marsh were exposed to greater tidal influence, it would be occupied by a smaller number of salt tolerant plants. Spartina is not found at Pescadero Marsh today. Its absence is due to one of a number of possibilities: (1) Spartina was present at one time, but high marsh development now occupies lower tidal channels and mud flats, and the Spartina was displaced; (2) suitable habitats are present but the plant never established itself or never reached this site; or (3) because of the topography and limited tidal influence within Pescadero Marsh, only higher marsh plants are present (MacDonald, 1977). Actually the absence of Spartina from this coastal marsh is not unique, since its presence in similar coastal areas is uncommon.

Natural drainage channels in the central part of the marsh have their own characteristic vegetation. These channels, which meander throughout most of this area, average 30 cm's to 90 cm's in depth. The deepest channels are totally filled with Salicornia virginica, while the channels with less than 30 cm's of water are lined with Scirpus robustus. The shallowest channels are again dominated by Salicornia virginica and Scirpus robustus disappears.

Although tidal influence at Pescadero Marsh is slight and reaches only a few drainages and those parts of the marsh adjacent to the main channels, flooding as a consequence of heavy rains or closure at the mouth does periodically inundate large areas of the marsh. The present pattern of marsh vegetation is, in part, a reflection of past circulation patterns, when more of the marsh was under the influence of tides.

Salicornia virginica is the dominant plant in this marsh. A more thorough examination of the factors influencing its distribution is needed. *Salicornia virginica* is much more tolerant of both higher elevations and more variable salinity than *Spartina foliosa*, which does not exist at Pescadero Marsh. Most recent studies (MacDonald, 1977) indicate that the lower limit of *Salicornia virginica* is due to poor seedling establishment because of prolonged tidal submergence. *Scirpus robustus* is the principal low marsh replacement for *Salicornia* at Pescadero Marsh. The factors controlling the landward distribution of *Salicornia virginica* remains unresolved, but competition may predominate in northern California (MacDonald, 1977). An experiment which is presented in the latter half of this section offers some explanation as to what factors control the distribution of *Salicornia virginica*, and other salt marsh halophytes in Pescadero Marsh.

The areal extent of salt marsh has been reduced in the past forty years. However, photos do not show the alteration of this vegetation type as vividly as those taken of the freshwater marsh. This is because the southeastern freshwater section has come under greater disturbance by man, and because the low growth form in salt marshes is more difficult to detect in photographs. However, some rechanneling and reduction in the original extent of salt marsh at its eastern boundary are visible (Figures 24 and 25).

Figure 24. A 1938 photo by Dr. Robert T. Orr of the salt marsh in the central area of Pescadero Marsh.

Figure 25. A 1978 photo of the same location seen in Figure 24. Levees are visible in the distance and channels appear to have been reduced in size over the past forty years.

Coastal Halophytes Zonation

There have been a number of studies of the vertical distribution of salt marsh plants (Purer, 1942; Hinde, 1954; Adam, 1963; Atwater and Hedel, 1976). The distribution of salt marsh halophytes seems to be determined by a number of factors, all relating to the elevation at which the plant is growing with respect to tidal inundations. The vertical range of salt marsh plants is very limited; a few inches rise in elevation may result in dominance by an entirely new species.

In the fall of 1978, soil salinity was tested along a transect in Pescadero Marsh. The experiment was designed to determine if varying degrees of salinity were responsible for morphological variation in *Salicornia virginica*. Morphological variation in *Salicornia virginica* is obvious in any given salt marsh, yet very little research has been conducted to determine the factors responsible for these changes, although salinity is suspect.

The salinity transect produced no conclusive evidence that changes in soil salinity are reflected in morphological variation in *Salicornia virginica*. Failure to produce such evidence was due to inadequate techniques used in measuring morphological characters of the plant, i.e., volume, diameter of the spikes, height of the plant.

However, a portion of this experiment is included in this chapter because it helps confirm other findings, that salinity and elevation are responsible for vertical zonation of coastal halophytes. The following information may also be helpful to those who are later involved in the management of Pescadero Marsh.

Methodology. A transect was run northwestward from a pond near the bank of Butano Creek to a point approaching a cultivated field. The transect extended 177 meters and contained 20 stations at intervals of 8.85 meters.

At each station a 15 cm core was taken, using a PCP pipe 3.5 cm in diameter. A 15 cm size core was chosen because most of the below ground biomass of Salicornia virginica exists in this zone (Mahall and Park, 1976). The core samples were placed in plastic bags, labeled and put into an ice chest and frozen to prevent evaporation.

Elevation along this transect was determined using a leveling device. There was a gradual rise from station A to Station T (Figure 26a). General topographic differences were noted along the transect, i.e., drainage channels, ditches, depressions and mounds, etc. The height of the plants and other measurements were taken. The depth of standing water was also recorded, as was the percent of dominance by any specific species within each station (station refers to a quadrat of approximately one square meter).

The salinity cores were brought to the laboratory, cut in half (7.5 cm), and weighed to determine the wet weight. They were then placed in aluminum foil, labeled and put into a drying oven and let dry for 48 hours at 100 C (212 degrees fahrenheit). The dried cores were then re-weighed to obtain the dry weight and the subsequent soil moisture of the original wet sample.

The dry cores were then pounded to a fine powder and 10 grams of each core (sub-sample) was placed into a 125 ml flask and labeled accordingly. Added to the flask was three times the percentage of water (distilled) that was in the original wet core. Aluminum foil was placed over the opening of each flask to prevent evaporation. The flasks were then put on the shaker table for two hours.

The soil-water solution was then placed in plastic tubes, labeled, and put into the centrifuge. The sample solutions were spun at 10,000 RPM's for 15 minutes.

Soil salinity was determined by two methods: a refractometer was used to get a reading in parts per thousand (Figure 26b), and the sight reading was tripled because of the addition of three times the amount of distilled water to each sub-sample. A salinometer was also used to measure the electrical conductivity in the sample. In general, growth of common crop plants is affected by salinity when the electrical conductivity of the soil paste is less than 2 mhos/cm. Salt tolerant crop plants may still grow, when soil conditions permit, even when conductivity increases to 8 mhos/cm. Some exceptionally salt-resistant plants may grow satisfactorily, even when conductivity of the soil is 10 mhos/cm. Only halophytes can survive when conductivity of the saturated soil extract exceeds these values (Richards, 1954).

Results and Discussion. Only *Salicornia virginica* grew at or above soil salinity measured above 10 mhos. High readings occurred within the first six stations (*A-F*), where density of *Salicornia virginica* was 100 percent. The only other station that exhibited total dominance of *Salicornia virginica* was station *M*, where a reading of 6.5 mho was recorded, which was the second highest reading found on the transect.

As was suspected, soil moisture was greatest at lower elevations, near the pond and pond depressions. It steadily decreased landward (Figure 26c). The highest percentage of soil moisture was 52 percent which occurred at station *B*, and the lowest was 39 percent occurring at station *S*. The average for the transect was 45 percent. There were two stations along the transect which had an abrupt relative rise in soil moisture, stations *M* and *J*. High soil moisture in M is explained by its proximity to a drainage channel, while that of J may be due to some subsurface feature such as an older channel which has since been covered by silt and vegetation.

Soil salinity decreased landward, with few exceptions, as indicated in Figure 26b. The salinity of the bottom core was higher than that in the top, in all but two stations (M and S). This phenomena is considered to be the winter relationship between salinity and soil depth according to Mahall and Park (1976). Increased salinity with increased depth is caused by the leaching effect of winter rains. However, at Pescadero Marsh, it had only rained on one occasion in the five months prior to the time the samples were collected. The flooding created by sand blockage at the mouth of the creek is responsible for the increased water in the marsh at the time of the study and the higher salinity in the bottom core.

Due to flooding of the marsh, the standing water in depressions and channels was relatively high. Figures 26a and 26d show the correlation between elevation and depth of standing water.

My findings support what almost every recent study has suggested, that *Salicornia virginica* is a better competitor as salinity of the soils increases. I also noted a bimodal distribution (dominance) of *Salicornia virginica* along the transect, an observation that MacDonald (1977) noted in *Salicornia* distribution in southern California.

Finally, as *Salicornia virginica* becomes less dominant, *Distichlis spicata*, *Frankenia grandifolia* and *Grindelia latifolia* become numerous, in that order. Salinity and elevation appear to be the critical factors along this transect, in determining halophyte zonation.

FIGURE 26A

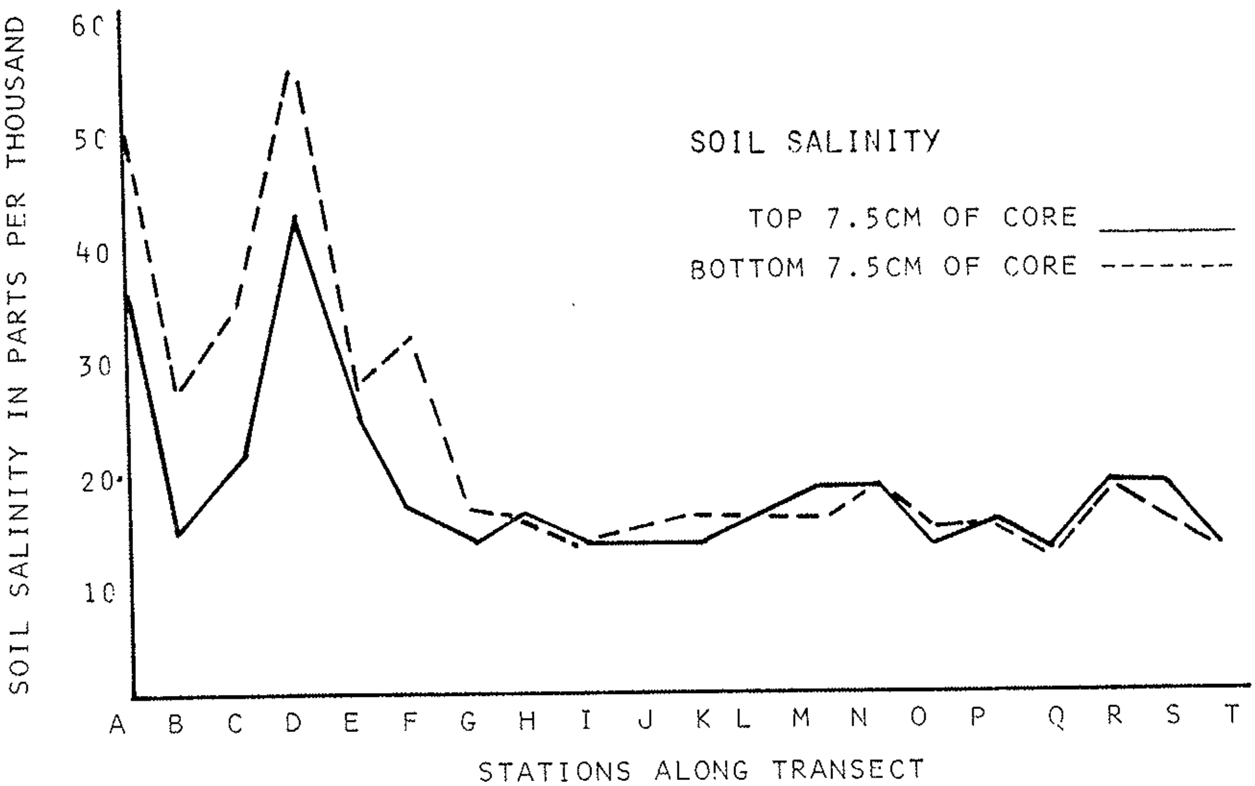


FIGURE 26B

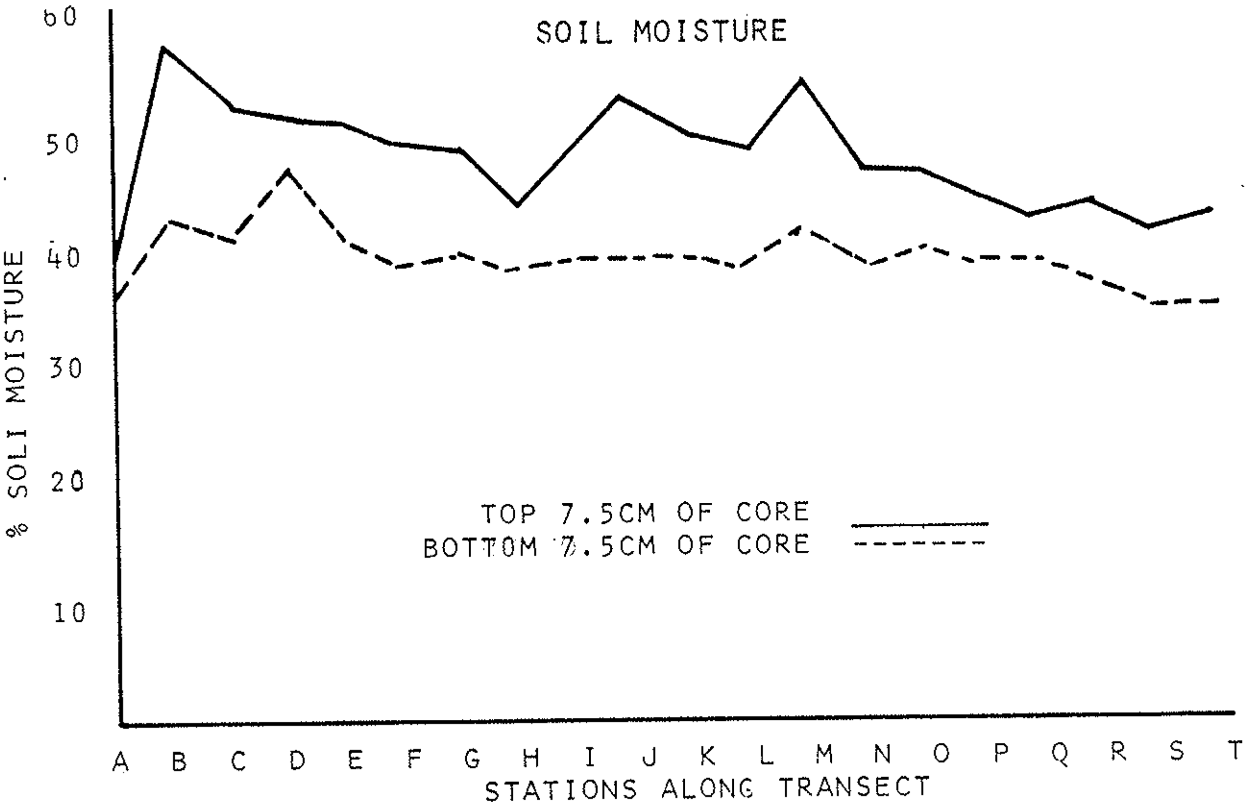


FIGURE 26C

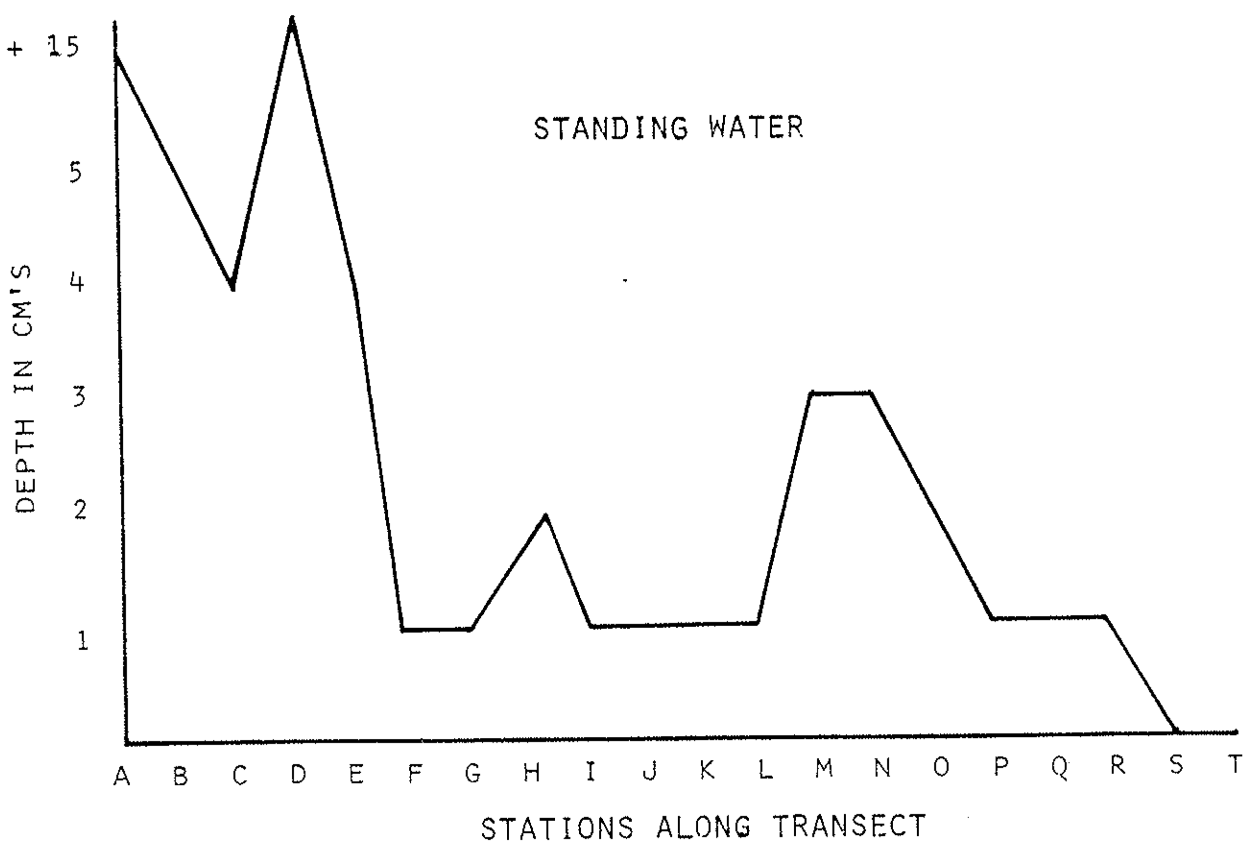


FIGURE 26D

Beach and Dune

Beach and dune vegetation include those pioneer plants growing along the strand as well as the more diverse groups in the foredunes and reardunes.

Extensive coastal dunes are unique, and where they occur a very specialized type of vegetation is found. Most of the California coast is made of cliffs and rocky shore, with only 23 percent of the 1326 km long coast occupied by beach and dune (Cooper, 1967).

Between San Francisco and Santa Cruz the most extensive coastal dune areas are in the vicinity of Ano Nuevo, Pigeon Point and those at the mouth of the Pescadero Creek.

Of all the vegetation types in the study area, the beach and dune plants suffer the greatest from human impact. Dune vegetation is sparse, relative to the surrounding types. Trampling and littering by weekend and summer recreationists in the dune area is becoming more evident each year. Hollows in between the dunes make for excellent shelter from coastal winds, and provide tempting places for picnics.

Damage to plants, and the build up of litter, therefore, is concentrated in these areas. Cardboard sleds are used to slide down the larger dunes, further damaging the delicate root systems. Measures need to be taken to offset the abuse of the dunes at Pescadero. Some suggestions concerning the proper management of Pescadero Marsh will be made in Chapter Five.

Although Indian habitation has apparently been responsible for at least one midden site in the reardunes, the dunes at Pescadero were probably in a pristine condition until approximately 1908. While railroad tracks for the Ocean Shore Railway were never completed south of Tunitas Creek, grading continued as far south as Pigeon Point (Miller, 1971).

According to a map identifying the right-of-way of the railroad from Tunitas Creek to Scotts Creek in the year 1913, the grading at Pescadero Beach must have followed the same route of the present day highway.

The next disturbance to the dunes, and probably the greatest, was the construction of Highway One itself, which was completed in 1941. Figure 27 shows the celebration which took place when the bridge at Pescadero Creek opened in 1941.

Figure 27. This photo shows definite changes in the vegetation of the dunes and along the road cuts as a result of construction (photo from collection of California Department of Transportation, San Francisco).

Figure 28 is a picture of the controversial "cofferdam" which was constructed across Pescadero Creek as a prelude to the building of the present-day bridge. Actually the word cofferdam is a misnomer, and refers to a haul road that was built by the State's contractor.

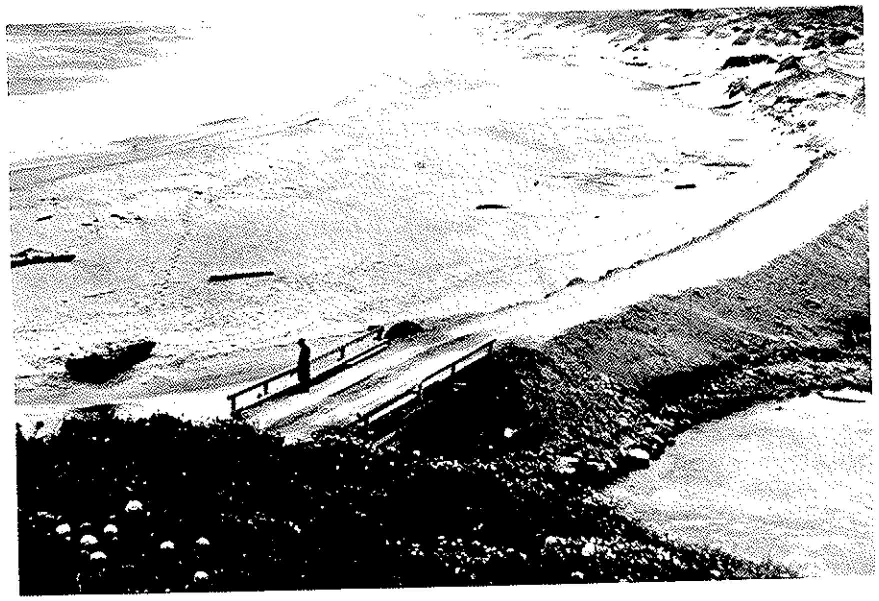


Figure 28. A photo of the haul road created during bridge construction in 1940 (from collection of San Mateo Historical Society).

As part of the haul road, a timber bridge was constructed which allowed the free flow of waters at the mouth. According to a report by CalTrans (Hayes, Walsh and Cassinelli, 1977), the earth materials used in the fill of this haul road "appear to have been mostly fine grained soils with very little rock."

However, Figure 28 does show some larger boulders at the base of the road. It is the present existence of these boulders in the channel directly opposite the old road, that has led residents to suspect that the haul road was never properly removed. Figure 29 is a present day photo of the boulders in question, as they line up with the road-cut made for the haul road construction.

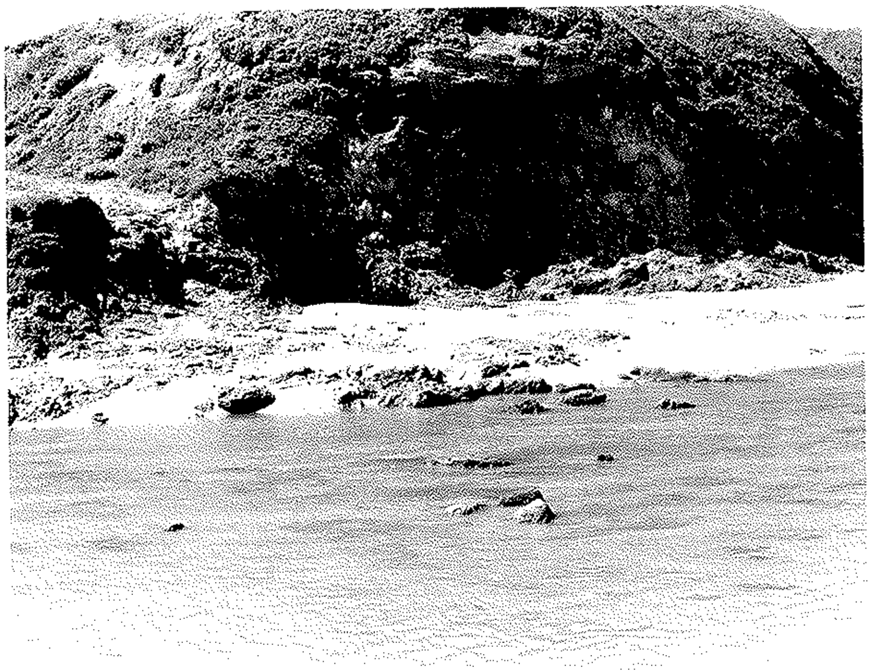


Figure 29. A 1978 photo of rocks opposite the old haul road. They appear to line up with the road which was cut into the cliff during bridge construction.

Local residents believe that the improper removal of these boulders, as well as some remaining pilings, has led to the silting-in of the lagoon east of the bridge. Prior to bridge construction in 1941, the lagoon was 16 to 18 feet deep in some places (oral communication, Frank Bell and Ron Duarte, 1978). Today, even at the highest tides, the water in the lagoon is never more than 5 to 6 feet deep in the deepest channels.

Sedimentation of the lower Pescadero Creek valley will be discussed more fully in the next chapter; however, observations of ground features, old air photos, maps, as well as interviews, have suggested that dramatic changes have taken place over the past fifty years.

The greatest human-related disturbance to the dunes occurred during the construction of the bridge across the mouth of Pescadero Creek. Figures 30 and 31 show how the dunes appeared in 1939 prior to bridge construction, and how they appear today, nearly 40 years later.

The addition of supporting rocks under the bridge as seen in Figure 33 and the planting of dune grass and Mesembryanthemum sp. (Sea Fig), have significantly altered the shape and height of the dunes in this portion of the beach.

Vernal pools, and what appears to be patches of sand verbena, are not present today along the north side of the creek (immediately east of the mouth) as they were in 1939 (Figures 32 and 33).

Present Dunes. Conditions for life become severe towards the shore, and the distribution of plants reflects these changes (Barbour, Craig, Drysdale and Gheiselin, 1973).

An increase in salinity, higher percentages of coarse sand and greater wind speeds, create conditions for a more severe habitat towards the shore. Eastward from the shore, diversity and density of species increase in response to milder conditions. Organic matter has accumulated away from the shore, and less saline conditions exist along with decreased wind speeds.

Because these habitats are essentially zeric, the plants which inhabit them are low lying, mostly perennials, and their foliage is either succulant or densely covered with some form of hair (Bluestone, 1970).

Dune topography is variable, and consists of foredunes, deflation areas, dune hollows, vernal pools, intermediate zones, reardunes, and a transition area

Figure 30. A 1939 photo of the dunes prior to construction of bridge across Pescadero Creek (from collection belonging to California Department of Transportation, San Francisco).

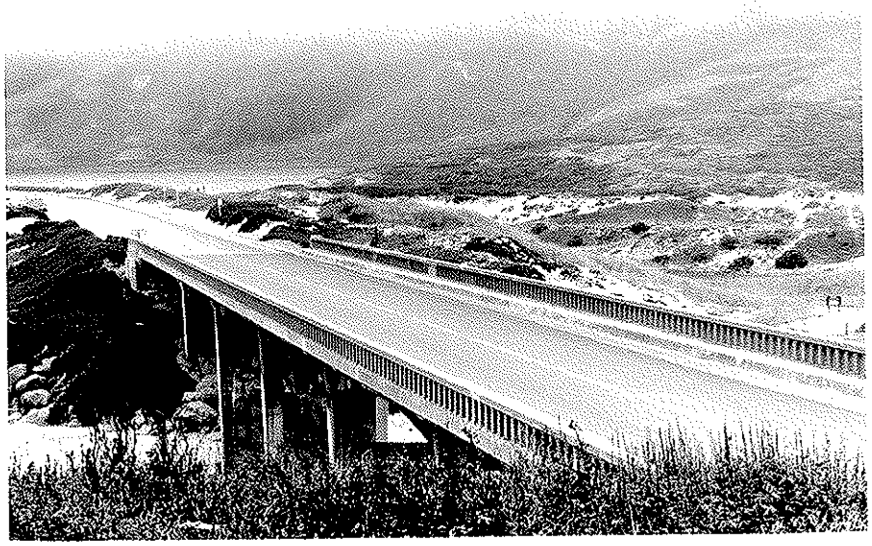


Figure 31. A 1978 photo of bridge across Pescadero Creek. Notice the changes in vegetation on the dunes that have taken place over the past forty years.

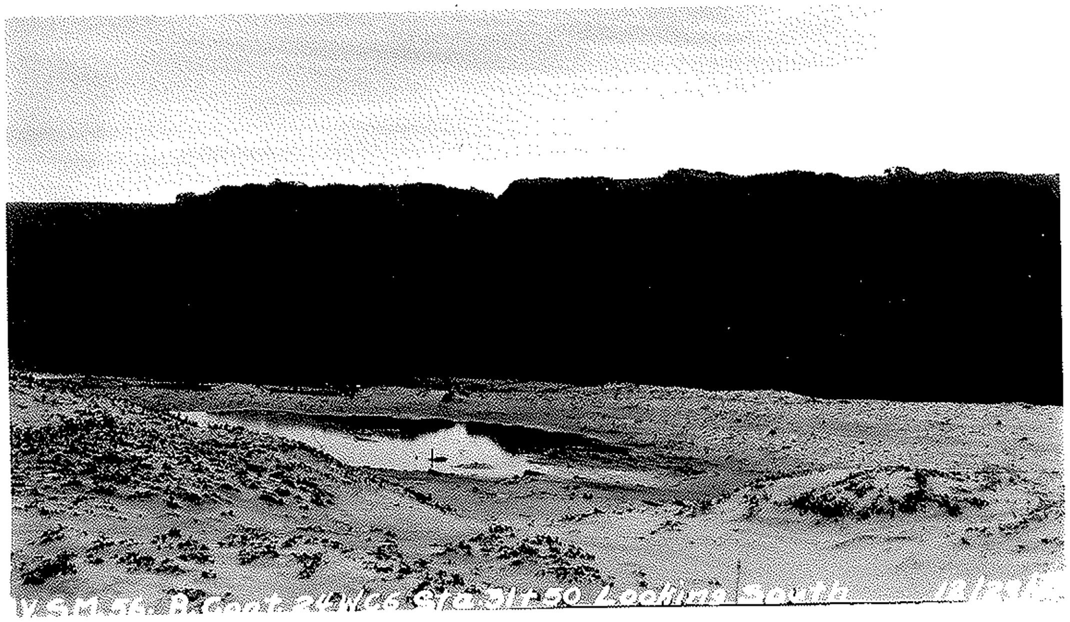


Figure 32. A 1939 photo of sand dunes on the north side of Pescadero Creek. Vegetation near the vernal pool appears to be sand verbena (from collection of California Department of Transportation, San Francisco).

Figure 33. A 1978 photo of dunes alongside the north end of the bridge. Sea Fig and dune grass now constitute the major plant cover of these dunes.

between the reardune and inland region. Species diversity will likewise depend upon the variety of dune topography in a particular area. The dunes that border Pescadero Marsh on its western margin, are extensive and form an interesting and variable habitat.

The beach is sparsely populated with *Abronia latifolia* (Yellow sand-verbena), *Franseria Chamissonis* (Beach Burr) and *Cakile maritima* (Sea Rocket). Dune grass is also found on the seaward slopes of the dunes near the bridge, as is *Mesembryanthemum* sp.

The foredunes midway along Pescadero Beach reach a height of 40 feet. Upon these dunes, the vegetation is fairly dense, with *Eriogonum latifolium* (Wild Buckwheat), *Castilleja franciscana* (Franciscan Paintbrush), *Abronia latifolia* and *Mesembryanthemum* sp. being the dominants (Figure 34). On the leeward side of the foredunes the dominant cover is *Artemisia pycnocephala* (Beach Sage Sagewort).

Behind the foredunes a vernal pond has developed west of the highway and across from the north pond. The pond may be present due to erosion associated with the construction of the highway. During winter and spring there is a fair amount of water in this hollow, with enough water lasting through the summer and fall to support willows, cattails, and a dense cover of silverweed and *Juncus* sp. (Rush).

East of the highway, the intermediate and reardunes are characterized by a somewhat richer flora. Here dune grass seems to be the most recent invader, as indicated from early photos and personal observations made during the past few years. Within the hollows were found both *Abronia latifolia* and *Abronia maritima* (Red sand-verbena), as well as California Poppy, Beach Morning Glory, and Wild Buckwheat (Figure 35). Lizard Tail, Yarrow, low forms of Coyote bush and *Juncus* appear to be the beginning of the transition zone and the end of the

Figure 34. Foredunes at Pescadero State Beach (photo taken in 1978).

Figure 35. Reardunes at Pescadero State Beach, east of Highway One (photo taken in 1978).

rear dunes.

It is interesting to note that in the lagoon west of bridge, *Cakile maritima* is the closest plant growing at the water's edge, while *Abronia latifolia* was found to take that position on the ocean side of the dunes. *Cakile maritima* is an introduced species, while *Abronia latifolia* is native. This may explain why the latter could be a better competitor in the harsher of the two environments.

Mesembryanthemum sp. has been planted along the north side of the lagoon. In recent times there has been a good deal of erosion as is evidenced by the exposure of its many roots.

Ruderal Vegetation

Almost one third, or 31 percent of the total number of 553 species of vascular plants growing without cultivation in the Santa Cruz Mountains are introduced (Thomas, 1961). Of the 250 taxa at Pescadero Marsh (species, sub-species and variety identified by Anderson and Morgan, 1975), 84 species or 34.3 percent of the flora is introduced. This figure is slightly more than that given for the entire Santa Cruz Mountain region, and may be due to the proximity of agricultural fields.

The greatest percentage of introduced plants are found on the levees, along trails and roads, and on other disturbed lands in and around Pescadero Marsh. The plants that grow in these places have been classified as Ruderal.

The degree of disturbance is variable and is depicted by the assemblage of plants. Some of the disturbance is continuous, while other sites have remained untouched for many years. Trampling, competition, and maintenance, as well as varying degrees of exposure to salinity and wind all contribute to species density and diversity within the marsh.

Nearly all the disturbed sites within the marsh were undisturbed prior to the turn of the century, with one exception. A road is shown extending from the town to the beginning of the reardunes, on an 1854 Topographic Survey map (Figure 57). The road was built on what appears to have been a natural levee.

The construction of a dirt road at the present site of Pescadero Road occurred in the early 1900s. Yet it wasn't until the late 1930s and early 1940s that the major network of levees was begun and Highway One completed. Construction of the levees and the draining of land continued into the 1950s and 60s.

Of the vegetation growing on these disturbed sites, the most common natives are: Baccharis pilolaris, Scrophularia californica (Figwort), Rubus ursinus (California Blackberry), Achillea borealis (Coast Yarrow), Juncus spp., Lupinus spp., and Potentilla Edgdei var. grandis (Silverweed), which grows on the lower sides of the levees and ditches.

The exotics reach their best development on the disturbed sites, since only a handful invade the saline habitats and other natural areas. The most common alien plants at Pescadero Marsh are the following: Conium maculatum (Poison Hemlock), Brassica campestris (Field Mustard), Plantago lanceolata (English Plantain), Raphanus sativus (Wild Radish), Cortula coronopifolia (Brass-Buttons), Rumex Acetocella (Sheep Sorrel), Anagallis arvensis (Scarlet Pimpernel), Avena barbata (Slender Wild Oat), Avena fatua (Wild Oat), Bromus mollis (Soft Chess), Cortadera Selloana (Pampas Grass) and Polypogon monospeliensis (Rabbit's-foot Grass).

The distribution of plants is markedly different throughout these disturbed areas. Certain factors seem to be responsible for these differences--the age of the disturbed site as well as the periodicity and degree of disturbance. As is the case with Beach and Dune vegetation, species density and diversity increases with distance from the sea.

Of all the areas classified as Ruderal, the roadside along the southeastern border of the marsh possesses the richest flora (Figure 36). Aside from the many natives and exotics already listed, many of the plants that follow are found nowhere else in the marsh: *Aquilegia formosa* var. *truncata* (Crimson Columbine), *Euphorbia Lathyris* (Gopher Plant), *Stachys bullata* (Hedge-Nettle), *Osmaronia cerasiformis* (Oso Berry), *Ceanothus thyrsiflorus* (Blue-Blossom), *Marah fabaceus* (Wild Cucumber), *Eschscholtzia californica*, *Iris Douglasiana* (Douglas Iris), and *Calystegia purpurata* (Western Morning-Glory).

Rhus diversilobia and *Rubus ursinus* are very common plants growing along Pescadero Road, and are co-dominants on the north side of the road.

The vegetation that is found along Highway One is not as well developed as that along Pescadero Road. Proximity to the coastal dunes, sea breezes and salt spray are responsible for the decrease in species diversity. Also, this is the area which receives the most pressure from human impact. *Brassica* sp., *Scrophularia californica*, *Achillea borealis*, *Eriophyllum staechadifolium* var. *artemisiaefolium* (Lizard's tail), and *Mesembryanthemum* sp. comprise 90 percent of the cover along the highway (Figure 37), not including the dune vegetation.

A seep is found on the west side of the highway, which parallels the north pond. Here the vegetation is markedly different than adjacent roadside vegetation. Willows, cattails, silverweed, and *Juncus* sp. are all growing here.

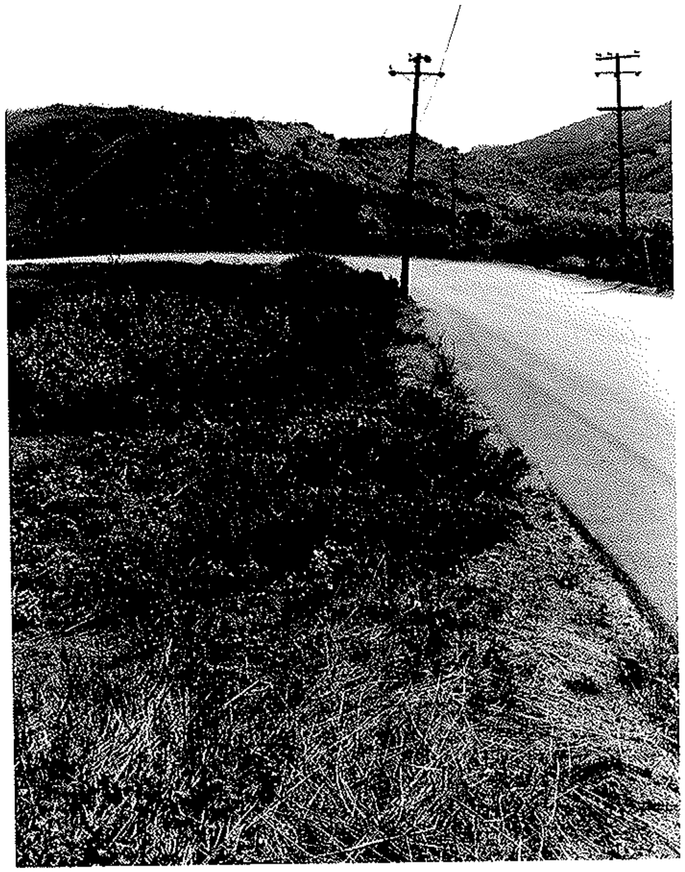


Figure 36. A 1978 photo of vegetation along Pescadero Road, which borders the southeastern edge of the marsh.

Figure 37. A 1978 photo of vegetation along Highway One, looking south. This seep commonly fills with water during wet periods. Across the highway is the north pond.

Levees at Pescadero Marsh are set apart from each other by their own characteristic vegetation cover. Although much of the plant cover is common to all the levees, their elevation and relative position with respect to salinity and other oceanic influences, help determine dominant plant cover. Also, the levees are of different ages, and the material of which they are constructed depends on their position within the marsh. The most landward levees are composed of coarse sand, whereas the levee nearest to the sea is silty. The reason for the difference in substrate is due to the sorting of materials which occurs as streams lose energy. The levee material is taken from ditches that have been dug adjacent to the levees.

For these reasons, extreme differences in plant cover exist between the most landward levees and those near the mouth of the creek. The levees exposed to the greatest oceanic influences are characterized by Cortula coronopifolia, Frankenia grandifolia and Grendelia sp., with Salicornia virginica lining the banks (Figure 38).

In contrast to this rather low growth composed of many salt tolerant species, the levee separating the north marsh from Pescadero Creek is significantly different both in flora and physical appearance Figure 39). Conium maculatum, Scrophularia californica and Baccharis pilolaris are the dominants, with Erechtites prenanthoides (Australian Fireweed) and Achillea borealis also being common. As this levee approaches the banks of Pescadero Creek, Salix (Willow), Alnus (Alder) and other riparian vegetation dominate the banks.

Levees in the intermediate areas exhibit vegetation from both the landward and seaward levees, as well as some of their own distinctive flora. Figure 40 is a photo of the levee which borders the present Vincent

Figure 38. A photo taken in 1978 shows this levee with a rich cover of Cortula coronopifolia. In the distance, and looking west, is the old Pardini property with its farm houses.

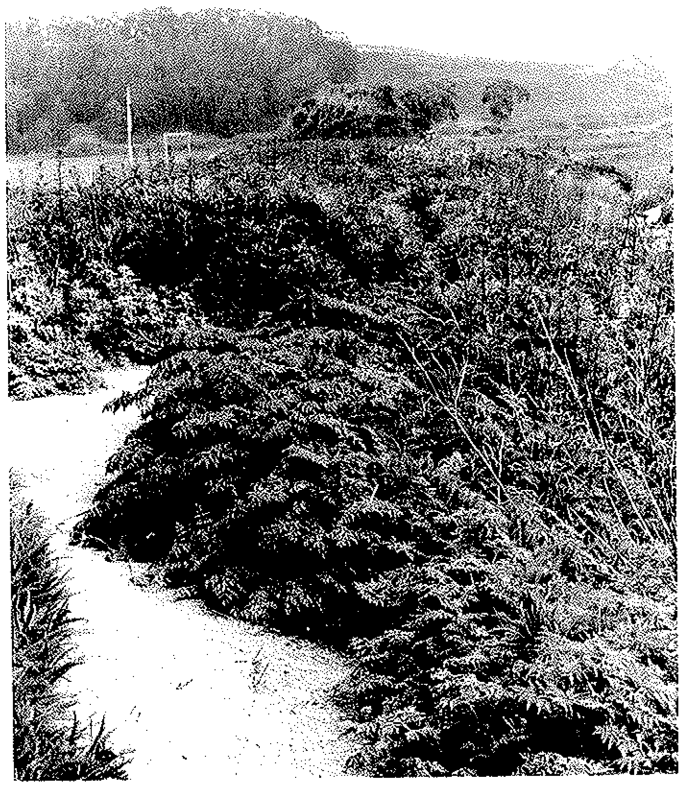


Figure 39. A photo taken in 1978 of the levee which divides the north marsh from the south marsh. The most common plant is the introduced poison hemlock. This levee was actually an old road which appears in an 1854 map (Figure 58). The view is looking east.

Muzzi land on its western edges. The most obvious plants in this photo are: *Polypogon monspeliensis*, *Rumex* sp., *Brassica campestris* and *Achillea borealis*.

Figure 40. A 1978 photo of a levee which transects the Vincent Muzzi property. Telephone poles in the distance are a relatively new addition to the marsh landscape. The view is looking north.

Riparian

The riparian vegetation is best developed outside the present reaches of Pescadero Marsh. However, the changes in vegetation with regard to changes in salinity upstream should be noted. Even though many, if not most, of these species are not often associated with riparian vegetation, they are the streamside vegetation throughout most of Pescadero Marsh.

Near the confluence where salinity was measured at $22^{o}/oo$ ($^{o}/oo$ = parts per thousand), *Scirpus robustus* inhabits the flat lower banks (Figure 41), while *Salicornia virginica* dominates the undercut banks. Further upstream on Butano Creek and around the first bend, *Scirpus californicus* is found growing on the opposite side of the creek from *Scirpus robustus*. Clumps of *Cortula coronopifolia* were also found. The salinity in these waters was recorded at $17^{o}/oo$. Still further upstream *Scirpus californicus* becomes more numerous, but *Scirpus robustus* is still abundant, and salinity falls to $8^{o}/oo$.

As river mile one is approached, the salinity was found to be $6^{o}/oo$. Here *Scirpus robustus* lines the northern banks, and the levees on the southside of the creek are covered with *Grindelia* sp., *Juamea carnosa*, some pickleweed and *Potentilla Egedei* var. *grandis* which inhabits the lower and wetter areas.

The salinity of the waters in Pescadero Creek, from the confluence upstream, was not systematically measured in the way in which that of Butano has been. After one week, the build-up of sand at the mouth caused the lagoon to flood and raised the water level in the lower channels, thus eliminating the influence of tidal flow. Only the record of the changes in

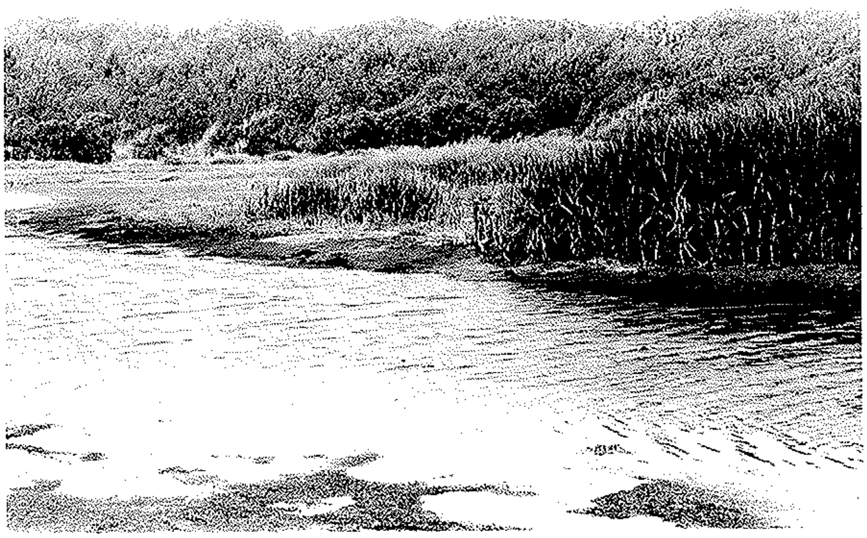


Figure 41. A 1978 photo of the vegetation along Butano Creek, 20 yards southeast of the confluence.

streamside conditions as depicted by the changes in plant growth could be made. In general, willows, alders, and cottonwoods (Figure 42) are encountered further downstream on Pescadero Creek than on Butano Creek.

Figure 42. Pescadero Creek streamside vegetation. Photo was taken in the vicinity of Round Hill in 1978.

Particle size of sediments in lower Pescadero Creek is greater than that found in the Butano system. The further extent of "true" riparian vegetation together with larger particle size, indicates that greater flows of fresh water occur in the lower portions of Pescadero Creek than in Butano

Creek. This is due in part to the larger drainage basin area in the Pescadero system. It would also follow that less salt water intrusion occurs up into Pescadero Creek.

Dense riparian vegetation was probably widespread along the streams which lead to the marsh. Figure 8 is an indication of the streamside conditions in earlier days. It is known that the Butano Flats, in Butano Valley, was once covered with willows, and that many acres of marshy land existed adjacent to the creek prior to their being cleared and plowed, which occurred in the 1920s (oral communication, Frank Bell).

A photo taken by R. T. Orr shows riparian growth as it appeared immediately south of the marsh, along Butano Creek (Figure 43). A present day photo of the same location (Figure 44) illustrates the almost total disappearance of the creek under a dense growth of willows and alders. In a recent conversation with Donald Louvere, of the Soil Conservation Service in Half Moon Bay, it was learned that the beaver was introduced in the early 1940s by the Service to control river flow. Dams were built, which resulted in the slowing of water and the accumulation of silt, followed by the spread of riparian vegetation.

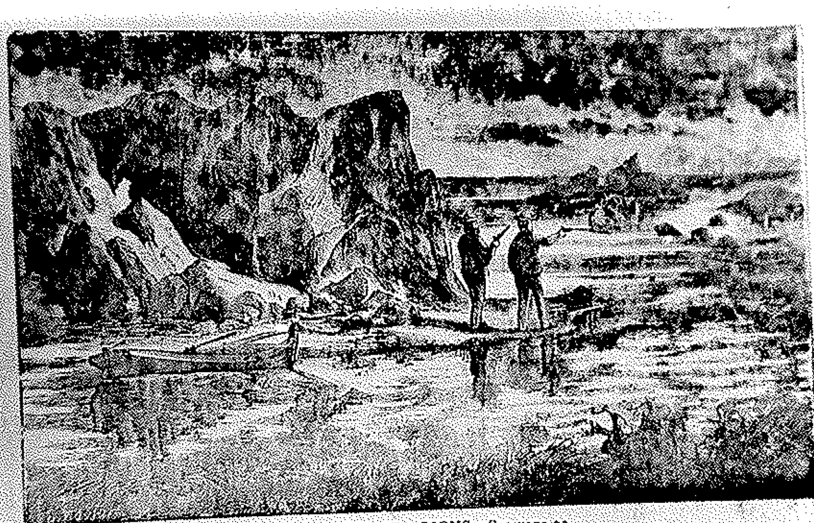
Pescadero Marsh Fauna

> The rocks we stood on, and which are covered at low tide, were incrusted with mussels of immense size. Some of them measure twelve inches in length, and Thompson tells me that he has seen them fifteen inches long.
>
> Colonel Evans, 1874 (mouth of Pescadero Creek, Figure 45).

The fauna at Pescadero Marsh is rich in diversity. But like the

Figure 43. A photo taken by Dr. Robert T. Orr in 1938 of lower Butano Valey. Butano Creek can be seen in the lower right corner, as it nears Pescadero Marsh.

Figure 44. A 1978 photo of lower Butano Valley, looking south in the same direction as Figure 43. Notice the creek has now become overgrown with willows and alders.



SHOOTING SEA LIONS.—See page 73.

Figure 45. An artist's conception of Colonel Evans at the mouth of Pescadero Creek in 1874. Evans and another man are depicted shooting seals just west of the mouth.

plants that grow at the marsh, the animal life has experienced disturbance by human-related activities. Some species have been totally eliminated from the area. The grizzly bear mentioned in many of the early logging stories in this area is no longer present.

Many of the larger mammals were still in evidence in Pescadero Valley and near the marsh until the latter part of th 1800s. Colonel Evans (Evans, 1874) helps to reconstruct the state of the animal life prior to modern times. On a boat trip through the marsh in the early 1870s, he comments, "Before we reached the mouth we saw two wolves on the opposite shore, running around at the edge of the breakers and playing like dogs."

Harbor seals are still common on the rocky coast south of the mouth of the creek. However, they do not enter the lagoon as they did in the past. During an interview with Frank Bell of San Gregorio, it was learned that seals were seen wallowing on the gravel banks of Pescadero Creek as far upstream as Round Hill.

Colonel Evans gives support to Bell's observations in the following passage: "The fish come into the creek with the tide, and bite best before the ebb commences. If the sea lions, who cover the rocks just outside (the mouth), follow them into the creeks, the fish all run out and there is no more sport that day" (Evans, 1874).

Historically, the animals that were most often associated with Pescadero were the fish which entered the mouth and spawned upstream in the basin. It has been said that the Spanish named the town Pescadero, which means "fishing place," due to the observations they made of the Indians frequenting the creeks with traps (Redwood City Tribune, June 9, 1960).

Evans insists that Pescadero is Spanish for "fishery." Whether the name implies "fishery" or "fishing place" is not important, the connotation is obvious enough. In early literature written about Pescadero, the sea-going trout that entered the valley were almost always mentioned. the most vivid of these early accounts is given by Colonel Evans:

> We went back to our boat as the tide came booming in, and prepared to fish for salmon-trout, as they are called; really they are yearling and two-year-old salmon. They will bite at a worm, spoon, or fly, but best at worms. I had hardly put in my hook before a noble fellow made the line fairly hiss through the water for a few minutes. Then we drew him panting and exhausted with his struggles, alongside the rocks, and with a landing net got him into the boat. He was twenty inches in length, and the handsomest fish I ever caught. Eight and ten pounders are common, and they are the most delicious fish for fish frying or broiling which ever swam the sea. Great crabs come in also with the tides, and we dipped several of them out with our nets. In two hours we corralled fourteen salmon-trout, losing several more by hooks breaking, and then the slack-water coming on and the fish refusing to bite with avidity, hoisted sail and went swiftly gliding back up the stream to the hotel. It was all and all, the best morning sport I have ever enjoyed in my life, and I have shot and fished from the Red River of the north to the Rio Grande, and from the Atlantic to the Pacific.

Although this is indeed a dramatic account of the game at the site of the marsh, fish continued to be plentiful up into the early 1900s. George Davis (Redwood City) remembers his father spearing salmon in the lagoon during the 1920s. Once, while using a row boat at nighttime with a lantern fastened to it, his father almost drowned when a spear he threw caused him to lose his balance and fall overboard. George remembers the channels as being much deeper in the 1920s.

Frank Bell also remembers the great fishing in the early 1900s. A photo, dated 1908, showed him with a string of some 16 steelhead trout, all of which appeared to measure over 12 inches. Both Davis and Bell remember the boat houses which existed at the eastern edge of the marsh. A man named Muck rented the boats to fishermen for a dollar a day. He lived in what Frank Bell referred to as an "arc," at the site of the old Pardini property, near the water's edge.

Ron Duarte, of Pescadero, talked of more recent days, in the 1940s and 50s, when the lagoon was still some 18 feet deep in certain places. He remembers the silver salmon runs to be somewhat sporadic, but the steelhead were much more consistent. He also remembers that the striped bass, Dungeness crabs, shrimp and clams were all part of the fauna inhabiting the waters upstream from the mouth. He attributes the decline in marine life to the construction of the bridge in 1941.

Today there are still runs of steelhead at Pescadero. The annual run of steelhead is estimated at approximately 1,500 fish each year, while the figures for silver salmon are not presently known. Other species of fish which have been reported in the lower streams are Pacific Lamprey, Prickley Sculpin, Threespine Stickelback, and the Starry Flounder (oral communication, Keith Anderson, California Department of Fish and Game, August, 1978).

A number of mammals have been observed in Pescadero Marsh during recent years. The writer has only seen a handful; these include deer, raccoon, rabbit, gopher and harvest mouse. However, local residents have seen many others, and they include: coyote, fox (gray), short-tailed weasel, badger, striped skunk, spotted skunk, bobcat, beaver, least chipmunk, pocket gopher, vole, wood rat, swamp rabbit, and the opossum.

On the north side of Pescadero Creek, in the vicinity of Round Hill, there is evidence that large numbers of deer frequent this area. A good quantity of deer droppings was found on the trails, and the brush was infested with ticks.

It is only in the last decade, since Chapman (1960) wrote about the salt marshes and salt deserts, that the abundance and significance of animals in salt marshes has come to be realized (Ranwell, 1972). Most of the recent literature seems to suggest a general lack of knowledge about salt marsh fauna.

There have been no systematic studies of the animals in Pescadero Marsh, other than those on the bird life. It is beyond the scope of this thesis to begin such a project; however, I hope that in the future others may decide to contribute information on population, distribution and ecology of the animals at this particular marsh.

Birds of Pescadero Marsh

The birds are the most conspicuous of the fauna at Pescadero Marsh. Because they receive the most attention by students and agencies, more is known about their numbers than any of the other types of wildlife in the marsh.

Part of this thesis was financed by the Sequoia Chapter of the Audubon Society, an indication of their concern for this valuable wetland. A current record of bird species needed to be collected, and a map produced showing the distribution of breeding birds at Pescadero Marsh. While I know many of the birds at the marsh, my knowledge is limited, and is a result of casual observations, rather than any attempt on my part to seriously study these birds. Therefore, it was necessary to call upon a trained person who could accomplish the professional job the Audubon Society was seeking. Peter Metropulos, who is extremely knowledgeable about the birds at Pescadero Marsh, contributed to this part of the project.

Using the same format as the Vegetation Map (Figure 11), Metropulos plotted the position of birds that were found breeding at the marsh in 1978. The results of the survey are included in Appendix A. Also included is a comprehensive list of all bird sightings at Pescadero Marsh during recent years, a list which was also compiled by Peter Metropulos (See Appendix B).

In discussing the recent history of Pescadero Marsh with local people, the prevailing view seems to be that the bird life within the marsh has always been rich. Duck clubs have come and gone and floating decoys, blinds and empty cartridges are a vivid indication of these days.

Colonel Evans comments on the abundance of bird life in the late 1800s: "The row down the creek was short, we saw hundreds of mallards and teal, which we could not shoot, because the law forbids it--very properly--until the 15th of the month, and large flocks of long billed curlew and other birds, such as crows, buzzards, gulls, etc., etc., which we did not want to kill" (Evans, 1874).

The first scientific record of the wildlife at Pescadero Marsh was given by Orr (1942). In this work he gives a brief physical description of the marsh and notes many of the birds which he sighted in 1938 and 1939. They include: American Bittern, Pied-billed Grebe, Black-crowned Night Heron, Great Blue Heron, Mallard, Pintail, Green-winged Teal and Cinnamon Teal. Refer to Orr (1942) for a complete listing of his observations.

In a personal interview with Dr. Orr on September 27, 1977, it was learned that there were no egrets at Pescadero Marsh in the late 1930s. "Egrets were pretty darn scarce, they were practically exterminated in the west due to the millinery trade." Thousands were preserved at Jungle Gardens on Avery Island in western Louisiana, which Orr visited in 1939. Eventually they were reintroduced into areas where they were previously found. Today the egret is very abundant at Pescadero Marsh, as they might have been prior to the turn of the century when they were not sought for their plumes.

There have been few studies since Orr made his observations in 1942. Bruce Elliot of the California Department of Fish and Game made a census for the year 1971-72. J. R. Patton of the California Department of Parks and Recreation completed a similar census for the year 1973-74.

However, the most comprehensive study to date was that made by Peter Metropulos, which is presented in its original form in Appendix A and Appendix B. This study divides Pescadero Marsh into six areas (Figure 66 in Appendix A). Within these areas, the breeding bird pairs are plotted numerically. Metropulos found 43 different species of birds breeding at the marsh during the season of 1978. There was a total of 369 pairs of breeding birds in all. These numbers were taken at the peak of the breeding season and represent an absolute minimum of the number of birds nesting in the marsh (Metropulos, Appendix A).

CHAPTER 4

PESCADERO MARSH EVOLUTION

Creation of Pescadero Valley

The previous chapters have primarily dealt with the evolution of Pescadero Marsh over a period of some 200 years, and projected that information a few years beyond to account for the Indian period. This chapter is concerned with events which led to the creation of the marsh itself.

Pescadero Valley was created by faulting (right lateral movement) and uplifting, which occurred over the past few million years (oral communication, Dr. Ken Lajoie). A number of newly discovered faults in the area (with a northwest trend) are now under investigation. One of these faults is exposed on a cliff face north of Pescadero State Beach.

Movement along the fault zone has caused the youngest terrace (north of Pescadero Creek) to move upward in relation to the older marine terrace (south of Pescadero Creek), which has been downfaulted.

Stream valleys formed in this faulted zone; the weathering and removal of material which followed carved out the present valley.

These processes took place over the past few million years and set the stage for events of the last 15,000 years.

Sea Level Changes

Pescadero Valley looked considerably different 15,000 years ago, and Pescadero Marsh did not exist. Still, the rivers that flowed through the valley and out to sea, probably originated at or near the same headwaters as Pescadero and Butano Creeks do today. However, they met the ocean some 15 miles west of the present shoreline. The sea level of 15,000 b.p. (before present) was nearly 100 meters (330 feet) lower than that of present times (Millimam and Emery, 1968).

Although the tectonic depression of the sea floor is a real factor in regulating sea level over long periods of time, the melting of glaciers is by far the overwhelming factor. Evidence clearly indicates that the rise and fall of sea level is directly related to the waxing and waning of the Ice Age (Fairbridge, 1960).

The change in sea level due to accumulation of great sheets of ice on land and their subsequent melting was a world wide phenomenon. Combining both paleobotany and radio-carbon dating, a general glacio-eustatic curve has been produced. According to Millimam and Emery (1968), the last interglacial high stand of sea level was near the present level about 30,000 to 35,000 b.p. (Figure 46). However, a recent study made of Holocene sea level changes in San Francisco Bay contradict the upper right section of the graph in Figure 46, for this section of the California coast. "Estuarine sediments of middle Wisconsin age appear to be absent, suggesting that local sea level was not near its present height 30,000-40,000 years ago" (Atwater, Hedel and Helley, 1977).

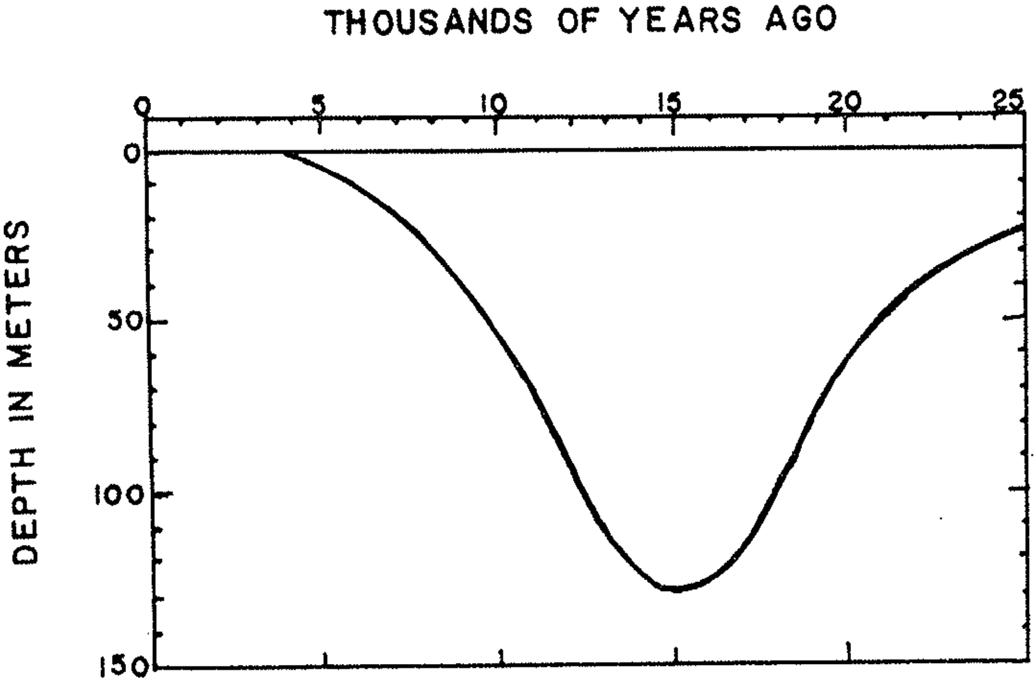


Figure 46. Sea level curve for the last 25,000 years (after Millimam and Emery, 1968).

World sea level fell slowly until 21,000 b.p. "Between 21,000 and 16,000 years ago it fell rapidly, reaching a maximum depth of -130 m. By 14,000 b.p. the Holocene transgression had begun and sea level rose rapidly until about 7,000 years ago, after which the rise was more gradual" (Millimam and Emery, 1968).

A curve produced by R. W. Fairbridge of sea level change in the last 20,000 years closely corresponds to the Millimam-Emery curve. He shows a rapid fall in sea level between 20,000 and 16,000 years ago, with the maximum low occurring around the 17,000 b.p. mark. At 15,000 years ago, sea level rose rapidly and continued to do so until it leveled off nearly 6,000 years ago. Fairbridge equates the 6,000 b.p. mark of sea level rise with the deluge recorded in ancient writings (Fairbridge, 1960).

Two recent papers give evidence as to the rate of sea level rise in San Francisco Bay during the last 10,000 years (Atwater and Hedel, 1976; Atwater, Hedel and Helley, 1977). According to the first of these reports, a rising sea entered the Golden Gate 10,000 years ago, and began to spread inland. For the next 2,000 years, the rate of sea level rise was 2 cm (0.8 inches) per year and advanced across gentle sloping areas as rapidly as 35 m (116 feet) per year. With the disappearance of the ice sheets, the rate of sea level rise decreased and has averaged 0.1 - 0.2 cm (0.04 - 0.08 inches) per year for the last 6,000 years. Evidence was based upon elevations and carbon-dating of plant remains from a number of core sites.

Stream valleys and estuaries have alternately occupied the San Francisco Bay for the past one million years (Atwater, Hedel and

Helley, 1977). There is no research which documents the extent and occurrence of estuarine conditions in Pescadero Valley over the recent geologic epoch. However, the configuration of borings taken for the placement of pillars and the construction of the bridge across Pescadero Creek (at Highway One), suggestes that a graded river valley existed at the site of the present Pescadero Marsh 15,000 years ago. Figure 47 is a profile of these borings made across Pescadero Creek at the Highway One intersection. Whether or not the profile is a picture of an older and a more V-shaped river valley, formed when base level was west of its present location, is not certain. Refusal of the boring device to penetrate substrata may be an indication of dense material, and not necessarily that of bedrock (oral communication, Adlai F. Goldschmidt, Engineering Geologist, Bridge Department, CalTrans, Sacramento, May 7, 1979).

However, gravel was found in test holes three and six at depths of -30 feet (9 meters) and -10 feet (3 meters) respectively (Figure 47). This is an indication that fluvial processes may have occurred at those depths and those locations in the recent geologic past, and hence a probable river bed existed prior to marsh formation.

Dune Formation

The most noticeable physical feature at Pescadero State Beach is not the 500 acres of marshland, or the mouth of the creek itself, but the towering dunes which reach nearly 40 feet in height. Like the marsh, these dunes are relatively new features in Pescadero Valley,

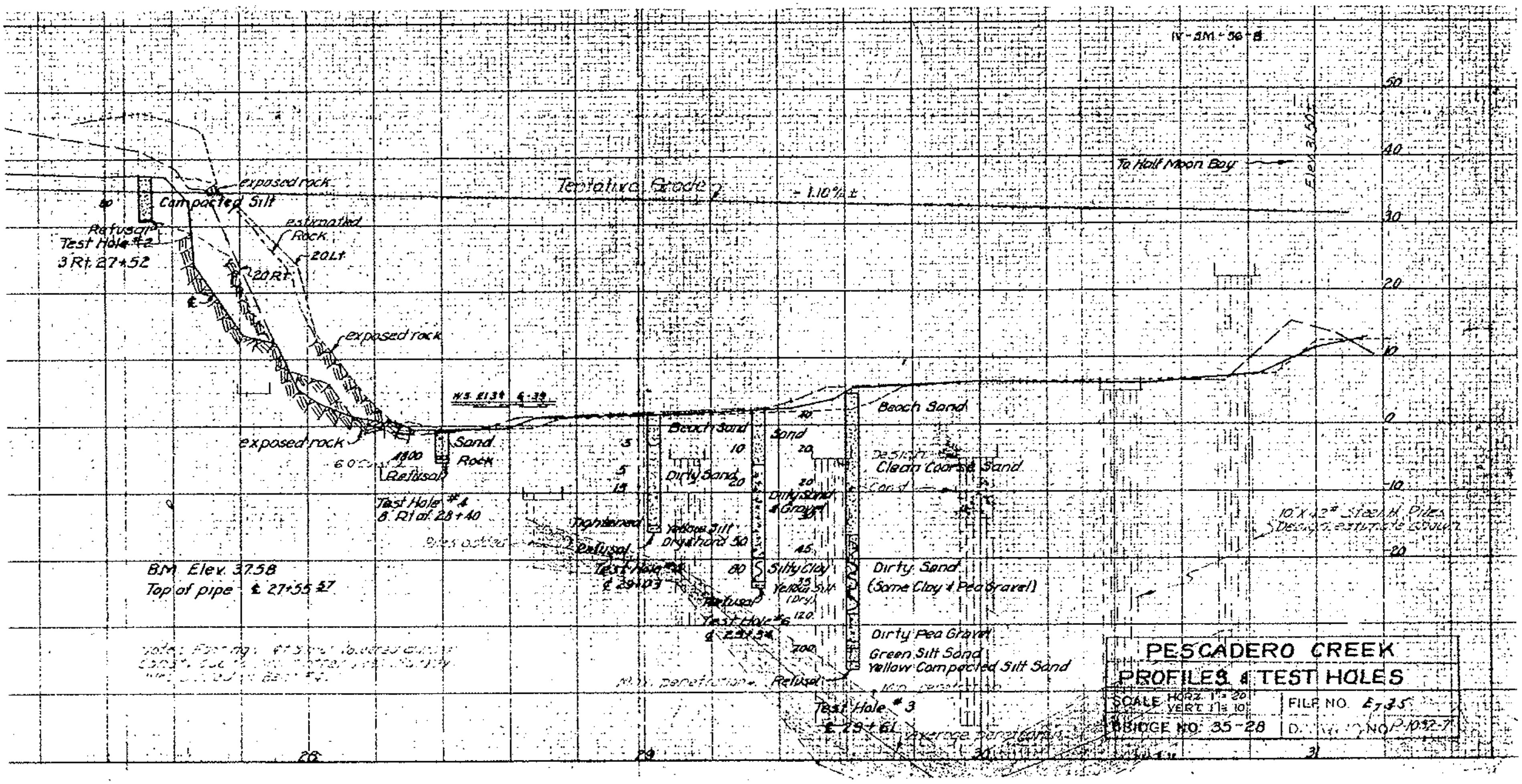


Figure 47. Profile constructed in 1939 during the construction of the Pescadero Bridge across Highway One.

and share similar histories as the muds and silts of Pescadero Marsh.

"The most significant event in geomorphic history with respect to the existing dunes and those of the recent past is the eustatic rise in sea level that accompanied the waning of continental ice sheets of North America and Eurasia" (Cooper, 1967). Dr. Kenneth Lajoie of the U.S. Geological Survey (Menlo Park) comments on a more local history. "The coast attained its present configuration of short, isolated beaches separated by rocky headlands as various processes modified the irregular western base of the California coast, during the past 4 to 5 millenia. Waves cut a prominent bench backed by steep sea cliffs along most of the coast and several large coastal valleys such as Pescadero Valley were flooded and subsequently alluviated as the streams adjusted their gradients to the rising sea level" (Lajoie, 1972). He continues, "Large tracts of sand derived from the encroaching beaches covered much of the San Francisco peninsula and dammed several small drainages forming lagoons and small lakes, the most notable is Lake Merced" (Lajoie).

The source of the sand which created the dunes and beaches appears to be mostly from cliff erosion, rather than from huge amounts of sand moving southward out of northern rivers (oral communication, Dr. Ken Lajoie).

We can probably get an approximate date for the beginning of dune formation by comparing Pescadero with Ano Nuevo, 11 miles south. A radiocarbon date of 2800 $\pm$300 years (U.S. Geological Survey W-1408) was taken from wood of the root system of a willow found in peat, resting in part on dune sand and in part in terrace deposits swept bare.

This information suggests that the peat is derived from wet ground vegetation, and that it began to accumulate not earlier than the invasion of the terrace by sand. Using the radiocarbon age of 2800 years for the willow root (0.7 m above the base of the peat) we get an estimated age of 4200 years for the basal layer of peat. It appears that dune activity at Ano Nuevo covers a minimum span of 3,000 years, and possibly as much as 5,000 years (Cooper, 1967).

It is reasonable to assume that Pescadero had a similar history with respect to dune formation.

Another interesting comparison exists between dune activity in Ano Nuevo and Pescadero. According to Cooper (1967), during the 1920s there was significant dune activity in the Point Ano Nuevo area. "Activity in the period 1919-1927 was high. On windy summer days clouds of sand blew from the dune summits, even passing horizontally out over Ano Nuevo Bay, finally settling, and making the water cloudy for a considerable distance."

This great volume of sand indicated to Cooper that in the past the amount delivered to the receptive northwest shore had been large. After the late 1920s, there was an abrupt halt to the movement of sand off the point. Cooper attributes this to the increase in irrigation and ground water, followed by the spontaneous spreading of native species and the stabilization of dunes. Any excess water would sink into the ground and move seaward in the terrace cover, following the gentle slope of the platform, and eventually reach the substratum upon which the dunes rest.

An air photo of Pescadero Marsh taken in the 1920s (Figure 48)

Figure 48. Air photo of Pescadero Marsh taken in the 1920s. Notice the large accumulation of sand in the north marsh (from folio of Ocean Shore Railroad, San Mateo County Planning Department, California).

shows sand reflecting brightly against the dark marsh background. This mosaic of air photos taken in the latter part of that decade, as part of an Ocean Shore Railroad series, depicted the only time large quantities of sand have been seen in this section of the marsh.

It would appear that Pescadero experienced similar degrees of sand movement as those which occurred an Ano Nuevo in the 1920s. Why the movement of sand ceased to show in all the later photos of Pescadero Marsh is uncertain. Dunes probably stabilized, although irrigation leakage at Pescadero is unlikely to have reached the dunes as it did at Ano Nuevo. Perhaps grading of the dunes in preparation for the building of the Ocean Shore Railroad is one possible reason why the increased dune activity is seen in the 1920s.

Sedimentation

Estuaries and coastal lagoons are ephemeral ecosystems; most throughout the world have been in existence only within the last six to five millenia.

As sea level reached its present level nearly six thousand years ago, coastal valleys were alluviated and marshes formed at the fringes of bays and rivers. The present study indicates that Pescadero Marsh had a similar origin.

"The town of Pescadero is present in an alluviated valley. The soils in the valley are equivalent to Yolo soils in the bay basin. Both are developed on alluvial deposits" (Lajoie, 1972).

Logs of wells in Pescadero Valley indicate that the sediments are about 15 meters thick and contain about 12 meters of clay. The Preponderance of clay is due to the widespread abundance of mudstone in the bedrock of the tributary basins (Koretsky-King Associates, Incorporated, 1976). The above information was obtained from review of over 40 well logs from the Pescadero area.

When comparing the bridge profile in Figure 47 with the record of well logs for the valley, it appears that the depth of Holocene deposits for the valley and the marsh area range between 12 and 15 meters thick. However, deep cores would have to be taken in the valley and near the marsh to determine the actual depth of these deposits.

The rate at which sediments will accumulate in a basin is dependent upon the source of supply (soils, bedrock, vegetation, etc.), geographic location and local climate. Humid regions have higher rates of sediment transport than arid climates.

Most temperate estuaries with moderate runoff are positive filled-basins (receiving their sediment from fluvial sources). Inverse-filled estuaries receive their source of sediment from littoral waters, eroding locally available deposits and carrying them into the basin through inlets. This latter type is found in areas of "deficient rainfall." Many modern temperate estuaries are to some extent a combination of each, receiving sediment from both fluvial an littoral sources, as well as reworking the basin sediment (Rusnak, 1967).

Analysis of deposits found in Pescadero Marsh suggest that the present site of the marsh has received sediments from both littoral and fluvial sources for at least the past two thousand years.

However, to what extent the sea invaded the present valley is unknown. If a number of deep cores were placed further up the valley, they could give valuable insight to that question.

An advancing sea probably reached the depression at the mouth of Pescadero Creek some 6,500 years ago (Figure 46), and spread inland. As stream energy decreased and the rate of sea level slowed, sediment accumulated in the valley, and on the mud flats and marshes.

The rate at which these sediments accumulated can be calculated knowing their depth above the pre-transgression surface. If we take 15 meters as an average depth for deposits that accumulated over the past 6,500 years, then we see an average sedimentation rate of 23 cm/100 years for that time span. However, with no evidence from deep cores (extending to bedrock) these geologic interpretations remain tentative.

> Neglecting the extremely high rate of accumulation represented by the deltas, we can estimate the rate of accumulation for the marginal marine environment with a probable error of no greater than a factor of two. These estimates are 2 m per thousand years for humid bays and estuaries, and 1 m per thousand years for arid and semi-arid lagoons. These rates apply only to the accumulation which has occurred since the last post-glacial rise of sea level, or to no more than about 10,000 to 15,000 years b.p. (Rusnak, 1967)

If we take the average of 23 cm/100 years and extend that to 2.3 meters as the average rate for 1,000 years, we receive a slightly higher rate of accumulation than 2 m/1,000 years listed as the average rate for humid climates (Rusnak, 1967). However, a Carbon 14 date from a basal layer of reduced peat at Pescadero produced an age of 1030 b.p. ±75 years (UM-1630) at a depth of 2 meters. The average rate of deposition at Pescadero for the past 6,500 years appears to be aound 2.1 meters/ 1,000 years.

The deposition rates for Tomales Bay (65 miles north) and Bolinas lagoon (45 miles north) during Holocene times are 22.5 cm/100 years and 30 cm/100 years, respectively (Rownetree, 1973).

Differences in rates of deposition are due to local geology, steepness of slope, and areal ratio between estuary and watershed, as well as the size of the basin.

Deposition in Modern Times. There are two reasons to believe that the rate of deposition has increased during historic times. First, there is a tendency for an estuary to increase its rate of deposition with age (Rownetree, 1973). Second, human-related practices such as logging, agriculture and road building must have added sediment load to the streams and tributaries of the Pescadero drainage basin.

Logging. The first saw mill built on the peninsula (south of San Francisco) was on Alambique Creek in the year 1848-1850. The activities of the saw mills in this area of the State got under way in response to the discovery of gold in the Sierra Nevada and the growing population pressures in San Francisco and other towns.

However, it wasn't until 1856 that the first saw mill was built within the Pescadero drainage basin. This mill was built by John Tuffley only a few miles east of the town of Pescadero. Logging has continued near the streams and tributaries in the basin ever since (Stanger, 1967). The locations of mill sites are plotted on the historical map in Figure 4. None of these sites are in operation today; the last saw mill closed in the late 1960s. However, logging still occurs on a limited basis in parts of the basin.

Due to relative inaccessibility and sparse population, the lumber was never completely cleared out, although there are accounts of mills being moved to new sites when local stands of lumber were exhausted.

It is difficult to assess the amount of sediment which was added to the marsh system since the advent of logging in the basin. However, recent studies verify the effects of logging on forest soil erosion. The major impact appears to stem from the construction of logging roads and the use of heavy mechanical equipment, much of which was absent from the mid-19th century logging scene (Rownetree, 1973).

Logging did take place well into the 20th century alongside the Pescadero and Butano systems. Residents in the Butano basin remember as late as the 1950s, the heavy mud flows which came through their land as a consequence of logging followed by heavy rains (oral communication, Mr. Twitt, San Mateo County Planning Department).

Figures 49, 50 and 51 give clear evidence of the condition of the land in the basin after logging in the 1920s. A good portion of this loose material probably made its way to the marsh in the years that followed.

Marsh Deposits

In order to determine changes at Pescadero Marsh during Holocene times, several cores were taken. Six core sites were chosen at locations which best represented the present extent of Pescadero Marsh (Figure 52). Cores were taken using a modified Eijekamp coring device (Dutch corer), on loan from Brian Atwater of the U.S. Geological Survey. Mr. Atwater instructed the writer in the use of the device and proper methods for record-

Figure 49. South slope of Pescadero Creek, logged during the fall of 1929 (photo taken June 24, 1930). From collection in the National Archives, Washington, D.C.

Figure 50. Looking south near Pescadero Creek (photo taken June 24, 1930). From collection in the National Archives, Washington, D.C.

Figure 51. Looking south near Pescadero Creek (photo taken June 24, 1930). From collection in the National Archives, Washington, D.C.

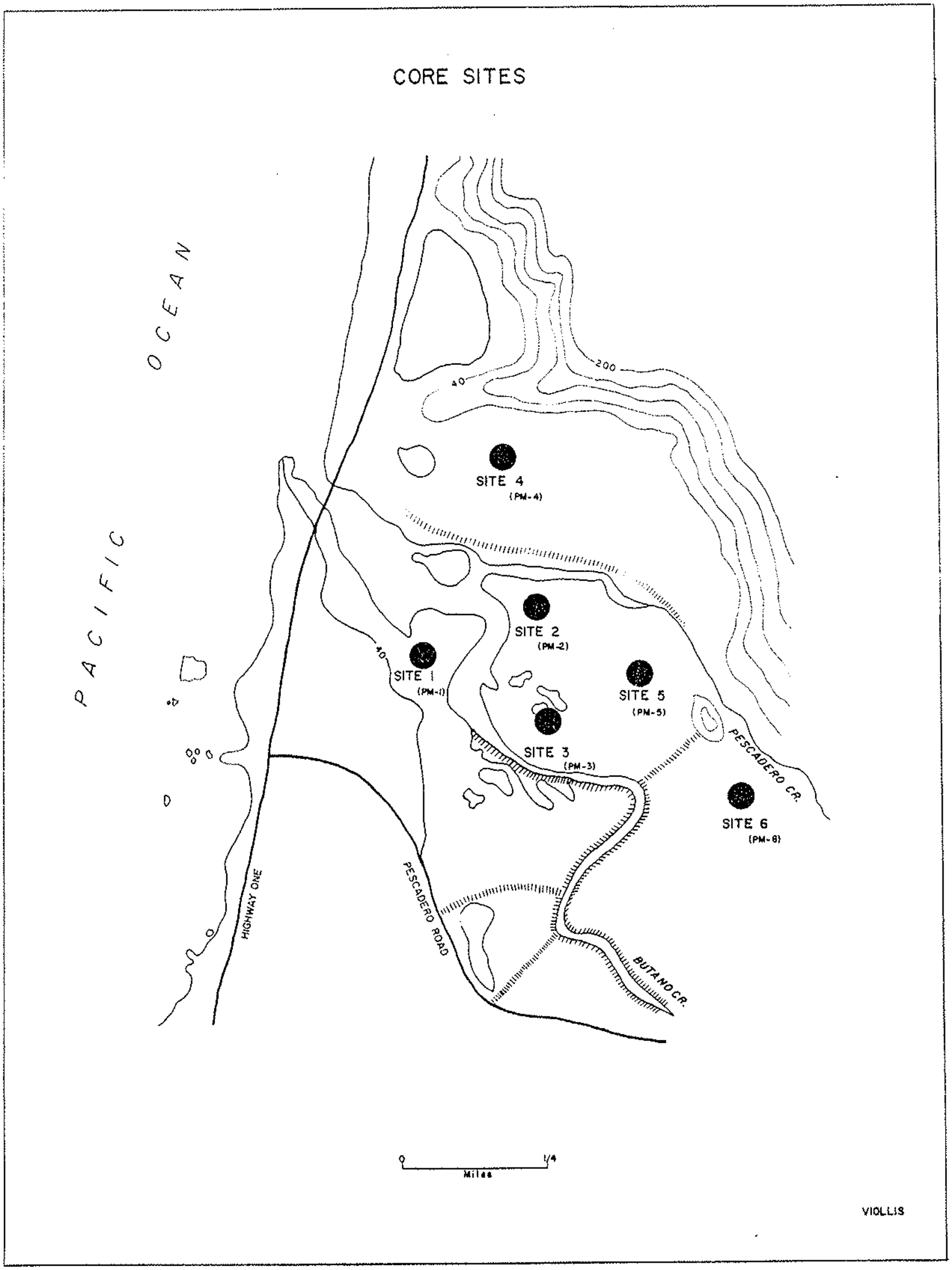

CORE SITES
PACIFIC OCEAN
200
40
SITE 4
(PM-4)
SITE 2
(PM-2)
SITE 1
(PM-1)
SITE 5
(PM-5)
SITE 3
(PM-3)
SITE 6
(PM-6)
PESCADERO CR.
BUTANO CR.
HIGHWAY ONE
PESCADERO ROAD
0
1/4
Miles
VIOLLIS

Figure 52.

ing marsh deposits, as well as providing insights into interpretation of the cores.

A diagram of each core was made in the field. Color changes were recorded according to the Munsell system for all but PM-1 (due to the unavailability of a chart at the time); particle size of sediment was also noted, as was the degree and consistency of organic material. The extent of plant material in growth position was recorded, providing a probable depth for the older marshes. A Carbon 14 date was obtained from a section of reduced peat at PM-3.

Many of the core sections were placed in plastic bags, labeled and brought into the laboratory where they were viewed under a binocular microscope. This last procedure was performed in order to verify observations made in the field, and to detect micro-organics.

General Observations. In general, observations made in the field were in agreement with those determined in the laboratory. The coring device produced an accurate picture of marsh stratigraphy. A photo of the coring device is seen in Figure 53.

Deposits consisted of silts, sands and clays of various consistency. Though some of the plant fossils were recognizable, most plant remains were decomposed to a point which made positive identification impossible.

Two sites (PM-1 and PM-2) produced definite marine fossils (bivalves). Ostracods were also found at these sites, although they have not yet been positively identified. Detrital material was found at all sites, and consisted of stems, rhizomes, fibrous bark (probably

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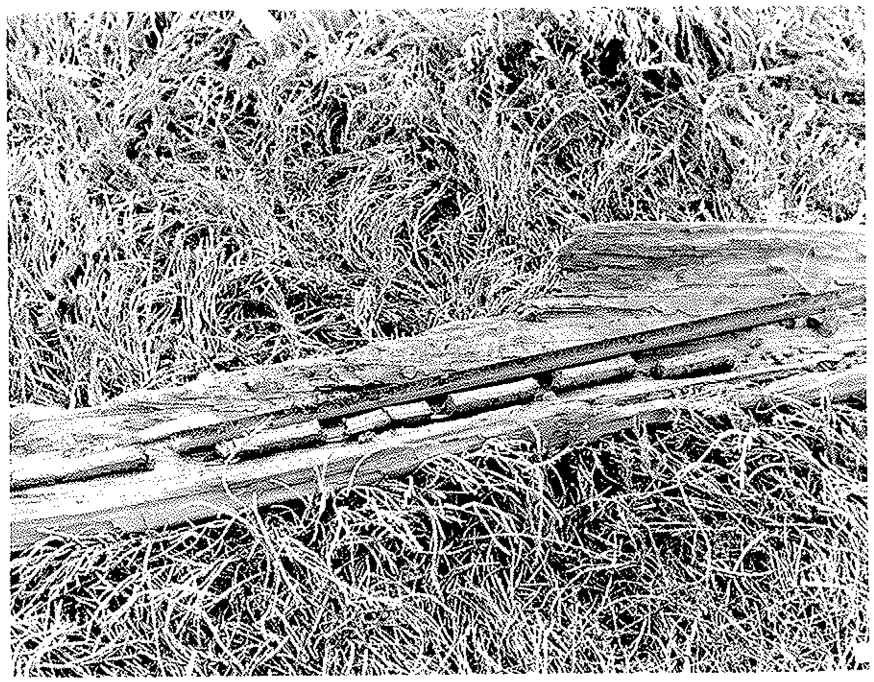


Figure 53. Modified Eijekamp corer (Dutch corer). The barrel diameter is 2 cm, with each extension 1 meter in length.

Redwood), charcoal and unidentifiable organic material. Hydrogen Sulfide odor was present throughout most of the deposits, as was iron staining on surfaces of root canals.

Marsh deposits had a marked similarity between sites, which indicates that salt marsh conditions have prevailed at this location for many years. The deposits found at the six sites are typical of salt marsh deposits recorded at other marshes (Reineck, 1967; Pestrong, 1972; Rigby and Hamlin, 1972; Mahall and Park, 1976; Atwater, Hedel and Helley, 1977).

Plant Material in Growth Position. Figure 54 shows the depth at each site where plant material was found to be in the growth position (vertically in place). Plant fossils consisted of the small roots and rhizomes of high-marsh plants (*Salicornia* sp. and *Distichlis* sp.) rather than the large rhizomes of low-marsh plants (*Spartina* sp. and *Scirpus* sp.). Other possible plant remains found in the cores could be those of eelgrass, which is rare or absent today at Pescadero Marsh.

It appears from the diagram (Figure 54) that marshes formed at greater depths furthest from the shoreline, thus marshes first formed landward and then spread seaward. This indicates that during the period recorded in the cores, sedimentation rates were greater than the rise of sea level. This also suggests that marshes probably did not extend much farther west than their present position.

Marine Fossil Remains. The depth and position of marine fossils in the sediment suggest that within the past few thousand years a deeper estuarine condition existed at the present site of Pescadero Marsh. At

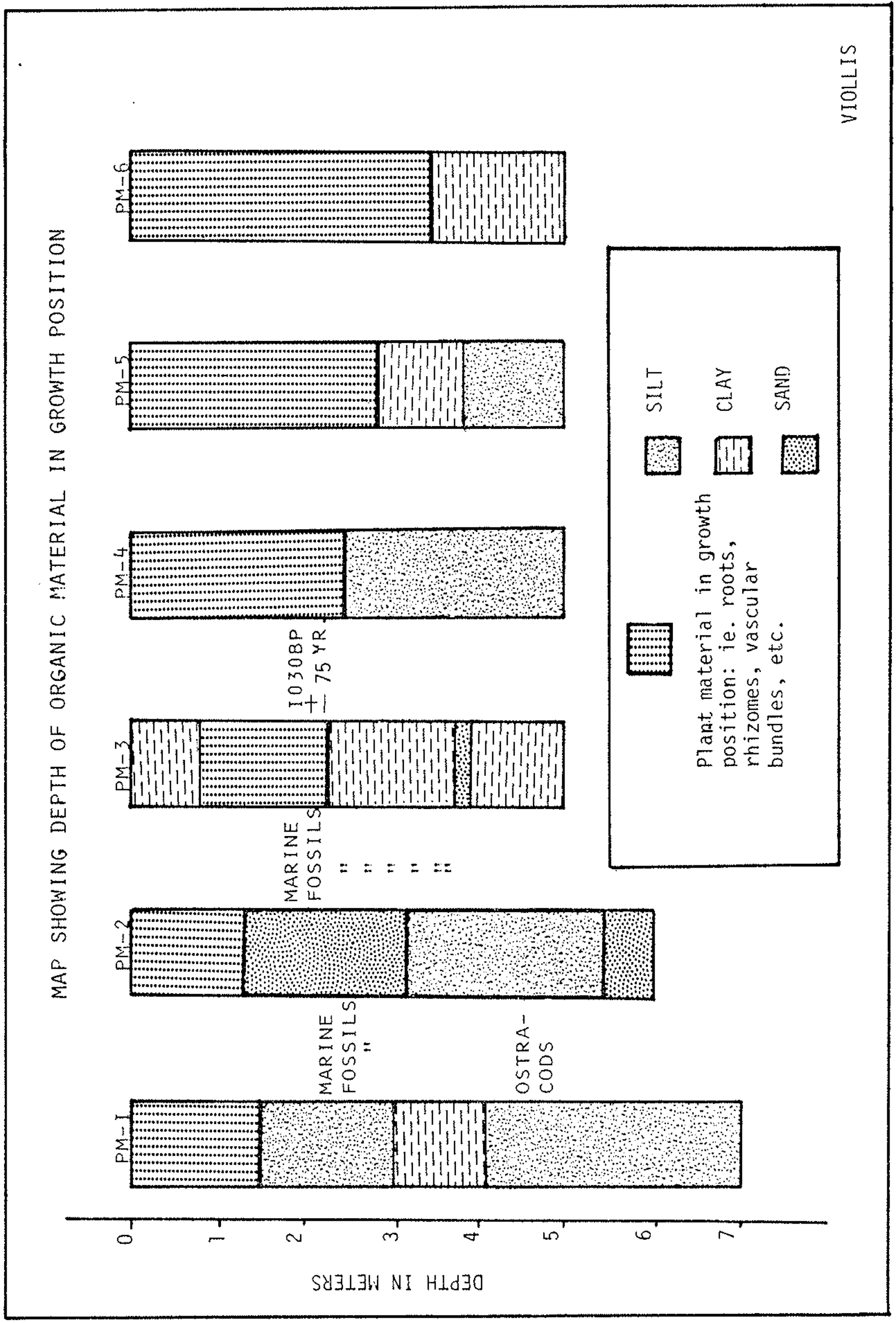

MAP SHOWING DEPTH OF ORGANIC MATERIAL IN GROWTH POSITION
VIOLLIS
PM-1
PM-2
PM-3
PM-4
PM-5
PM-6
MARINE FOSSILS
"
OSTRA-CODS
MARINE FOSSILS
" " " " "
1030BP ± 75 YR
Plant material in growth position: ie. roots, rhizomes, vascular bundles, etc.
SILT
CLAY
SAND
DEPTH IN METERS
0
1
2
3
4
5
6
7

Figure 54.

both PM-1 and PM-2, marine bivalves were found as well as Ostracods. These beds were found at depths of nearly two meters and extended for another 2 to 3 meters (Figures 55a and 55b). The site of PM-2 is nearly 230 feet inland from the present confluence, an indication of the amount of sediment which has accumulated in the past few thousand years.

The shell fragments which accumulated at these two sites probably were washed in when sea level was much lower, and these sections of the core were exposed to tidal flushing. The preponderance of shell fragments within the two cores may prove to represent locations of older drainage channels which flowed across mud flats and young marshes. Shell fragments have a tendency to concentrate in drainage channels (Pestrong, 1972). Drainage channels which were once connected with tidal flows are now mostly cut off from circulation. Changes in vegetation mark the existence of older channels, whose subtle relief differences would not otherwise be visible. These channels were more extensive before man modified the marsh by constructing levees.

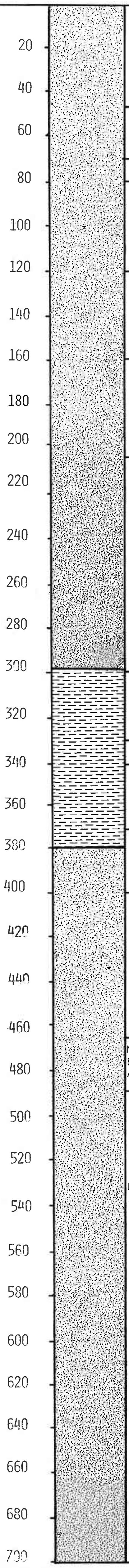
Still conditions were very different when these shells were exposed to sea water. Pectin, found at a depth of 3 meters at PM-2 (Figure 55b), is rare or totally absent from the littoral zone at Pescadero today. Its occurrence suggests that deeper water conditions existed at this site. The collection of enough shells at these locations could produce an important Carbon 14 date, valuable in recording sea level changes during Holocene times.

Ostracods were found at both PM-1 and PM-2, at a depth below 4 meters and in the absence of large shell fragments (bivalves). This may have represented a period of relatively deep water in the estuary, when wave action was not reworking the sediments.

PM-I

DEPTH IN CM'S

SURFACE: THE SURFACE VEGETATION AT THIS POINT CONSISTED OF A THICK COVER OF SALICORNIA VIRGINICA.



COLOR

- LIGHT & GRAYISH BROWN
- DISTINCTLY BANDED
- DRK. GRAY & GRAY
- GRAY
- GRAY W/ INDISTINCT BROWN BANDS
- GRAY
- GRAY MODELED W/ GREEN-GRAY
- GRAYS IN INDISTINCT BANDS
- BANDS OF GRAYS & BROWNS
- GRAY
- BANDS OF GRAYS & BROWNS
- GRAY
- MEDIUM DARK GRAY
- MODELING OF DRK. GRAY AND GREENISH GRAY
- MEDIUM DARK GRAY
- "
- "
- "
- "
- "

SEDIMENTS

- SILT W/ BANDS OF VERY FINE SAND
- SILT W/ BANDS OF VERY FINE SAND 2CM THICK
- SILT W/ INDISTINCT BANDS OF VERY FINE SAND (.5MM THICK)
- AS ABOVE (HOWEVER BANDS BECOME 1MM IN THICKNESS
- AS ABOVE (HOWEVER BECOMING CLAYEY)
- CLAYEY SILT W/ FINE SAND
- SILTY CLAY
- SILT
- CLAYEY SILT
- "
- "
- SANDY SILT
- SILT
- SILT BECOMING CLAYEY IN SECTIONS

ORGANIC MATERIAL

- PLANT MATERIAL IN GROWTH POSITION (SALICORNIA VIRGINICA-LIVING)
- CORE PEATY "
- 2MM PIECE OF CHARCOAL
- RED STAINED : EPIDERMIS, VASCULAR BUNDLES
- 2 RHRIZOMES OR STEM BASE
- PLANT MATERIAL BOTH IN GROWTH POSITION (VERTICAL) AND IN THE HORIZONTAL POSITION
- FIBROUS PLANT MATERIAL IN GROWTH POSITION
- "
- "
- PLANT MATERIAL BECOMING SPARSE
- NO ORGANICS
- "
- "
- "
- SPARSE ORGANICS BUT APPEAR TO TO BE IN GROWTH POSITION.
- OSTRACODS PRESENT
- DETRITAL MATERIAL (STEMS, ETC.)
- EXOSKELETON OF CRUSTACEAN
- OSTRACODS VERY NUMEROUS
- PLANT MATERIAL IN GROWTH POSITION (INTERMITTENTLY WITHIN THE FOLLOWING METER, 1MM IN DIAM).
- MATERIAL HEAVILY DECOMPOSED (H2S ODOR THROUGHOUT)
- "
- "
- (POSSIBLE RHIZOME: 5MM IN DIAM W/ NODES)
- NO ORGANICS
- "
- PLANT MATERIAL VERY SPARSE(ONE ROOTLIKE STRUCTURE 1MM IN DIAM. APPEARS TO BE IN GROWTH POSITION) HEAVILY DECOMPOSED
- "
- OSTARCODS
- "
- "
- PLANT MATERIAL VERY SPARSE (ROOT-LIKE STRUCTURE 1MM IN DIAM.) THEY APPEAR TO BE IN GROWTH POSITION. HEAVILY DECOMPOSED. H2S ODOR PREVAILS
- (THE ABOVE CONDITIONS IN THE CORE EXTENDS TO A DEPTH 630 CM'S)
- "
- "
- "
- "
- NO ORGANICS.........
- "
- "
- "

Figure 55a.

Figure 55b

PM-2

DEPTH IN CM'S

SURFACE: CORE TAKEN AT A POINT APPROX. 250 FEET EAST OF THE PRESENT CONFLUENCE. S. VIRGINICA & D. SPICATA ARE DOM.

DEPTH IN CM'S	COLOR	SEDIMENTS	ORGANIC MATERIAL
0–20	5yr3/2 modeled w/ 5y4/5	PEATY SILT	PLANT MATERIAL IN GROWTH POSITION (APPEARS TO BE DISTICHLIS SPICATA) CORE VERY PEATY AT THIS POINT.
40			"
60	5YR4/1		"
80			PLANT MATERIAL IN GROWTH POSITION CONTINUES AS ABOVE.
100	5YR2/1	SILT BECOMING GRITTY	"
		SILT WITH VERY FINE SAND	ORGANICS IN GROWTH POSITION BECOMING SPARSE.
120			"
140		FINE SAND	AS ABOVE .....
160	5Y3/1 MODELED W/ N1	FINE SAND W/PEBBLE (1.5CM IN LENGTH & 1CM IN WIDTH)	NO ORGANICS FOUND BETWEEEN 150CM AND 200CM.
180			"
			"
200	5Y3/1	SILTY SAND	MARINE BIVALVES
220			FRAGMENTS OF DETRITAL PLANT MATERIAL. STONE: .5CM IN DIAM PIECE OF CHARCOAL
240	5Y2/1	SILT W/ VERY FINE SAND	MARINE BIVALVES ARE PRESENT THRU THE FOLLOWING METER (240CM TO 350CM DEPTH)
260			240-260CM: CRYPTOMA CALIFORNICA MACOMA NASUTA
280			260-280CM: MACOMA NASUTA CRYPTOMYA CALIFORNICA
300			280-330CM: MACOMA NASUTA (TWO PROBABLES) ARGOPECTIN AEQUISULCATUS AND OR CLINOCARDIUM NUTTALLI
320		SAND	
		SILT	
340		CLAYEY SILT	PIECES OF DETRITAL MATERIAL (APPEARS TO BE THAT OF REDWOOD)
360	5Y3/1		
380	5Y4/1		DETRITAL MATERIAL CONTINUES.
400			MARINE BIVALVES AT THIS POINT
420	5Y3/1	SANDY SILT	DETRITAL MATERIAL APPEARS AGAIN.
440	5Y3/2		ROOTLIKE STRUCTURE FOUND IN GROWTH POSITION, THIN (LESS THEN 1MM IN DIAM.) RESEMBLES THOES SEEN IN PM-1 (400CM TO 630CM). THESE RELATIVELY THIN PLANT MATERIALS IN GROWTH POSITION EXTEND TO THE END OF THIS CORE.
460		CLAYEY SILT	
480			"
500			
520	"		"
540			"
560			"
580	"	BANDS OF FINE SAND AND CLAYEY SILT	SMALL SHELLS (POSSIBLY OSTRACODS)
600			

Ostracods were associated with thin root-like structures (less than 1 mm in diameter) found in the growth position. These are found at a depth of 4.4 meters for PM-1 and 5.6 meters for PM-2. The plant material may be that of a sub-tidal species of eelgrass. Plant remains were markedly different from those found in the above sections of the core; they appeared thinner and their total growth in the core was sparse.

Sediments. The stratigraphy seen in the cores taken at Pescadero Marsh points to events typical of coastal marsh evolution. The distribution of sediment is controlled by stream energy and wave action.

Sediments were colored gray, with the deeper sediments appearing greenish-gray. Banding of grays and browns occurred at sections in the core which had a high degree of organic content. Within these apparent salt marsh deposits, were alternating bands of sand and silt. These conditions reflect the periodic flooding which is so common in salt marshes.

Another feature of salt marsh growth is the presence of sharp color changes, i.e., between black, brown and gray. These changes are indicative of periods of deposition, oxidation and reduction.

Zones of little or no organic material were fairly uniform in color (grays and grayish brown).

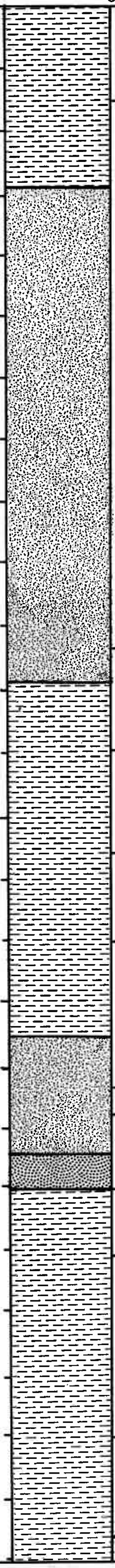
Meandering streams or channels must have deposited sand at most of the sites (Figures 55c, 55d, 55e, and 55f). The sand lenses at these sites were relatively thick, indicating proximity to streams or tidal action.

The greatest percentage of clays existed at sites PM-5 and PM-6, the probable area of least stream and wave action. Finer sediments are

Figure 55c.

PM-3

SURFACE: CORE TAKEN IN DRIED POND WHCIH HAD CLUMPS OF <u>SALICORNIA VIRGINICA</u>.



DEPTH IN CM'S	COLOR	SEDIMENTS	ORGANIC MATERIAL
0–20	NO INFO	SILTY CLAY W/ IRON CONCRETIONS	CORE CONTAINED A FEW ROOTS, (TOP 30 CM' OF CORE FELL APART) CORE CRUMBLED, HEAVILY STAINED WITH IRON.
40	5Y4/1	CLAYEY SILT W/ IRON CONCRETIONS.	"
60			"
80		CLAYEY SILT	"
		FINE SILTY SAND	Peaty material: roots in growth position
100		CLAYEY SILT W/ DENSE BANDS OF PEATY PLANT MATERIAL.	(rhizome or root, 2mm in diam.)
120	"		roots in growth position, most less then 1mm in diam. (very peaty)
140			H2S odor is prevalent throughout the remaining core.
			"
160			peaty material in growth position
180			"
200			core becoming very peaty (plant material appears in growth position, (rhizome, 2mm in diam. ?) CARBON 14 DATE : 1030 BP± 75 YRS. (MATERIAL DATED WAS PEAT IN ITS REDUCED STATE)
220	5Y2/1		
240	5Y3/1	SILTY CLAY	plant material becoming sparse, some plant material may be in growth position-less than 1mm in diam..
260			"
280	5GY4/1		"
300	5Y2/1		"
320			continues as above
340		SILT MODELED WITH CLAY	"
360	5GY4/1		"
	5Y2/1		
380		SAND	"
400	5GY3/1	SILTY CLAY	"
420	5GY3/1 MODELED W/ 5GY4/1 + 5Y2/1		a few pieces of detrital material found in this last meter of PM-3, no other organics.
440			"
460			"
480	5Y4/1 W/ 5Y2/1		"
500	5GY 4/1		"

PM-4

SURFACE: CORE TAKEN IN THE NORTH MARSH, THROUGH A DENSE COVER OF SALICORNIA VIRGINICA (PLANT VERY WELL DEVELOPED HERE)

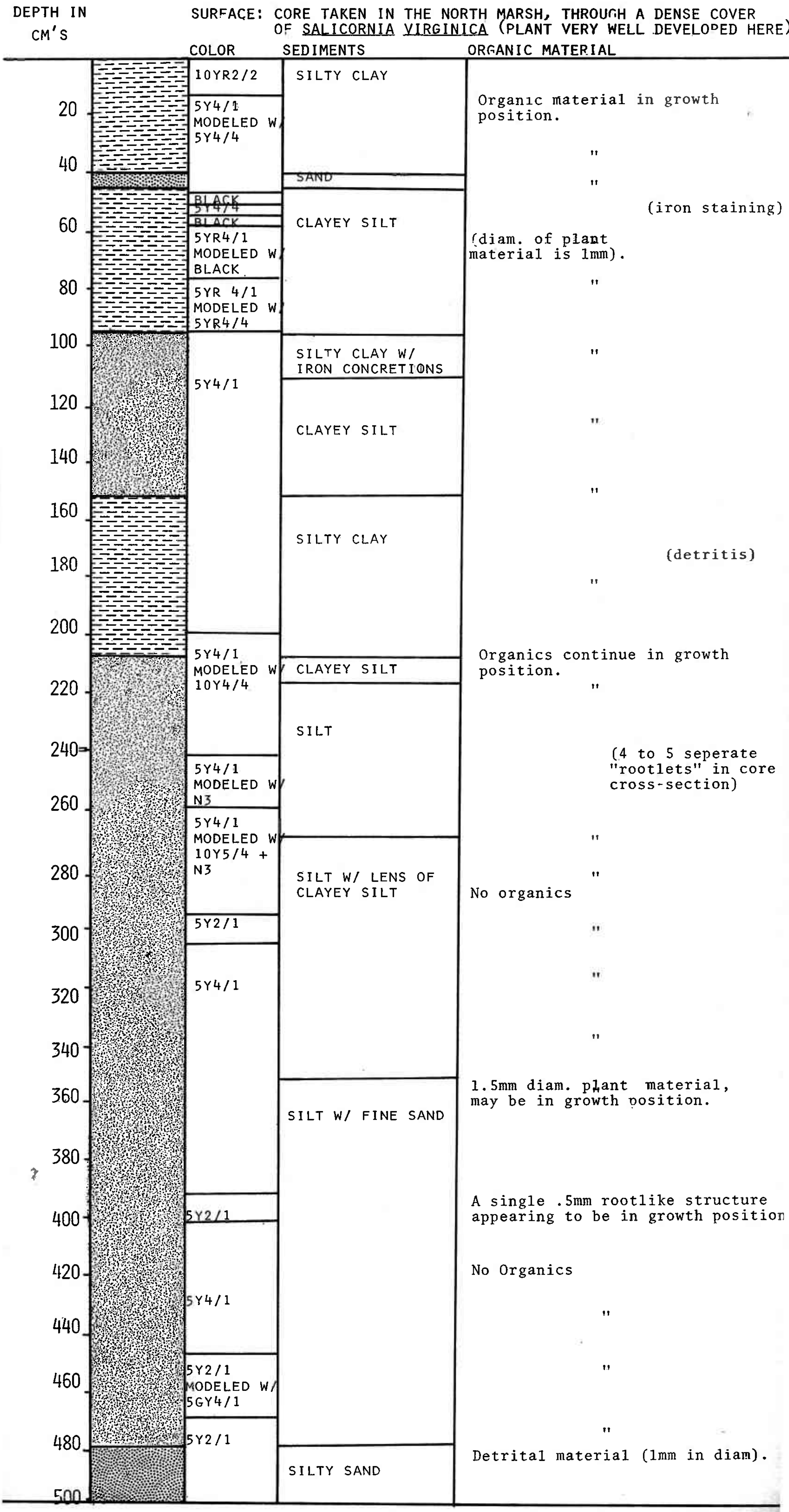


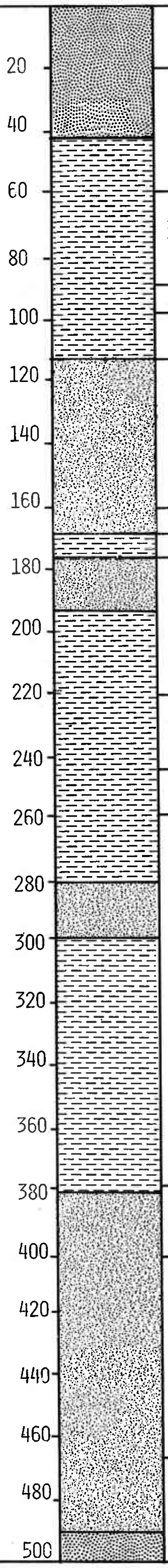
Figure 55d.

Figure 55e.

PM-5

SURFACE: CORE TAKEN AT A POINT IN THE MARSH WERE <u>SALICORNIA VIRGINICA</u> WAS GROWING WITH <u>DISTICHLIS SPICATA</u> AND <u>GRINDELIA LATIFOLIA</u>.

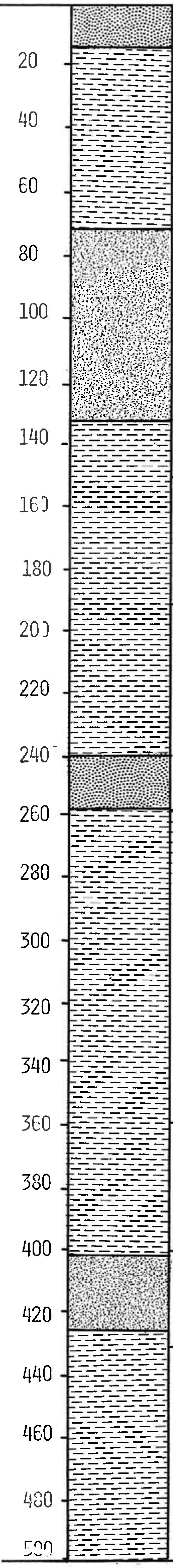
DEPTH IN CM'S



COLOR	SEDIMENTS	ORGANIC MATERIAL
5y5/2	Sandy Loam w/iron concretions	Numerous roots in growth position (appears to be that of <u>Distichlis spicata</u>.
5y4/1	Silty Sand	Very Peaty (numerous organics in growth position)
	Silty Sand banded with organics.	"
10yr3/2 modeled w/dark gray		" "
XX lost	this section XXXXX	XXXXXXX
5y3/1	Silty Clay	Very Peaty as above
5y3/2	Abrupt change to Silt.	"
	Silt w/very fine sand	Rootlike material in growth position (extending 30cm in length.) Organics in growth position, becoming sparse.
5y2/1		
N3	Clay	
5y3/1	Clayey Silt	"
	Silty Clay	
5y3/1 modeled by 5y4/4	Iron concretions	"
5y2/1		
5gy4/1		"
	Silt	"
	Silty Clay	No organics visible " " "
5gy4/1 modeled w/5y4/4	Sandy Silts	"
5gy4/4	Clayey Silt	Two strands of rootlike material. (possibly in growth position, 1mm in diam.). No organics visible
	Silty	"
5y3/2 modeled w/5y4/4	Sandy Silt w/very fine sand.	Detrital material less then 1mm in diam.
	Loamy Sand	

PM-6

SURFACE: CORE TAKEN IN A FIELD THAT HAD ONE TIME BEEN CULTIVATED. MANY INTRODUCED WEEDS ARE PRESENT, AS IS GRINDELIA SP.



COLOR

10YR2/2
10YR3/2
10YR3/2
10YR 5/6
XXXX
10YR3/2
5Y2/I
5GY4/1
5G4/1
5Y2/1
5Y3/1
5GY4/1

SEDIMENTS

SANDY LOAM
LOAM BECOMING CLAY-LIKE.
CLAY LOAM WITH ORANGE AND BLACK MODELING.
MODELED BY: 5YR5/6
XXXXXXX
CORE FELL APART
SANDY SILT
IRON CONCRETIONS
DENSE CLAY
MODELED WITH 5Y4/4
SILTY CLAY WITH CONCRETIONS
SAND
SILTY CLAY
SILTY CLAY W/ FINE SAND
SILTY CLAY
CLAY
SILTY CLAY
CLAYEY SILT
SILTY CLAY W/ VERY FINE SAND.

ORGANIC MATERIAL

Pieces of straw, roots, seeds, etc.
"
"
"
XXXXXXXX
Few organics
Organic material in growth position.
2mm in diam.
"
"
"
"
Large "root" in growth position
5mm in diam.
Organic material in growth position.
"
"
Organics in growth position. 2mm in diam, 2cm in length.
"
Detrital material

Figure 55f.

deposited near the high water line, and in protected parts of an estuary. The coarser sandy sediments lie at the low water level, in drainage channels and along streams (Reineck, 1967).

An interesting section of sand is that at the bottom of PM-4 (Figure 55d). Further coring of this hole may result in the location of an older channel, which may have meandered along the bend in the north marsh and entered the sea in the vicinity of the north pond. This hole was abandoned when it collapsed.

Pollen Analysis. A preliminary pollen study was conducted at Pescadero Marsh by Deborah Dorland, a graduate student in geography at San Francisco State University. Two core sites were chosen, corresponding to my PM-2 and PM-3.

In general, the study produced high and low percentages of *Potemogeton* (Pondweed), which indicated that there was a periodic fluctuating hydrology in the marsh. Although *Potomogeton* is listed in Anderson and Morgan's *A Flora of Pescadero Marsh*, its occurrence today is rare. *Potemogeton* is an aquatic plant which grows mostly submerged in relatively calm water that is fresh to moderately saline.

Another interesting result of the pollen study was the existence of *Ephedra* (Mormon's tea) at PM-3. This plant is commonly associated with arid environments. It is not presently found in the Santa Cruz Mountains. The closest habitat where *Ephedra* can be found is on the east slopes of Mount Diablo, about 50 miles east of Pescadero Marsh. It is common east of the Sierra Nevada.

The remarkable occurrence of its pollen grains in Pescadero sediment, less than 1,000 years old, have interesting implications as to dramatic local climatic changes within very recent times.

Further pollen studies undertaken at Pescadero Marsh would help classify changes in climates and hydrology in the region.

Historical Development

Even to the casual observer it is clear that man has dramatically modified the physical and biological nature of the marsh.

This section is devoted to the most obvious changes, those of levee construction, reclamation of marshland, and the building of roads along the outer boundaries of the marsh.

Figure 56 is an undated Diseno (early Spanish map), of Rancho El Pescadero. The location of the confluence is the only recognizable point which marks the position of the marsh. This is the first pictoral description of the land bordering Pescadero Marsh, and was probably drawn in the early 1830s.

In 1854, a topographic survey map of Pescadero was made (Figure 57), later to be revised in 1894. It is the first technical map of Pescadero Marsh. One interesting feature of this map is the presence of a trail (a double dotted line) extending from the dune area towards town. This trail appears to be located on a natural levee, marked by upland vegetation symbols. The appearance of this symbol on either side of Pescadero Creek, indicates that a natural levee and road existed prior to construction of modern levees in this part of the marsh.

Using Round Hill as a guide (Figure 57), it is easy to see that the marsh extended further east and southeast of its present boundary. No other trails or levees are visible in this first true map of Pescadero

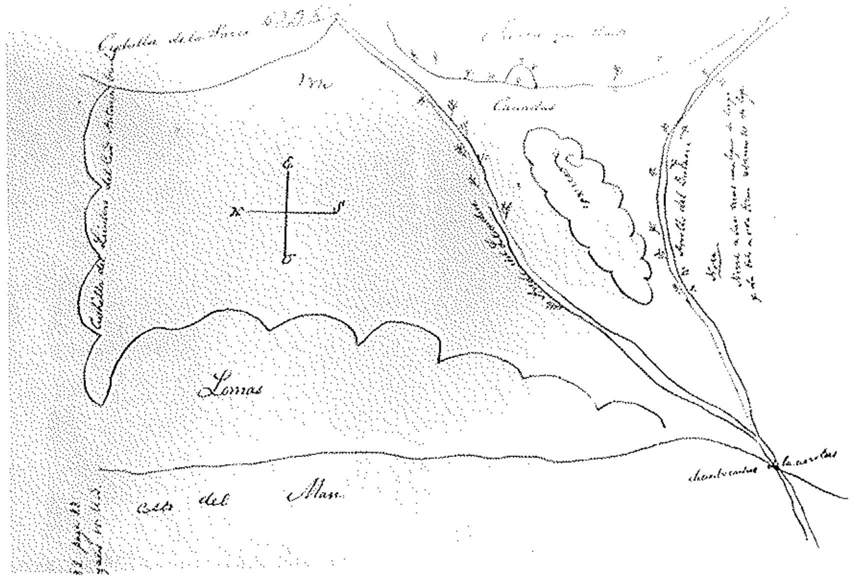


Figure 56. Diseno of Rancho El Pescadero (California State Archives, Sacramento).

Figure 57. Map of part of the coast of California from Punta Del Bolsa Northward to Tunitas Creek (U.S. Coast and Geodetic Survey No. 682, dated 1854).

Marsh. The dune orientation in the map is northwest by southeast, as it is today, reflecting the same prevailing wind conditions over the past 100 years.

In 1874, a map was made showing the route of the Pescadero Railroad (Figure 58). This railroad was never built, but the map still remains in the California State Archives at Sacramento. A faint line at the southern end of the marsh shows the proposed route, just south of Butano Creek. A dotted line south of the marsh shows the existence of a road that joined the town of Pescadero with points to the south, i.e., Pigeon Point, Davenport, and Santa Cruz.

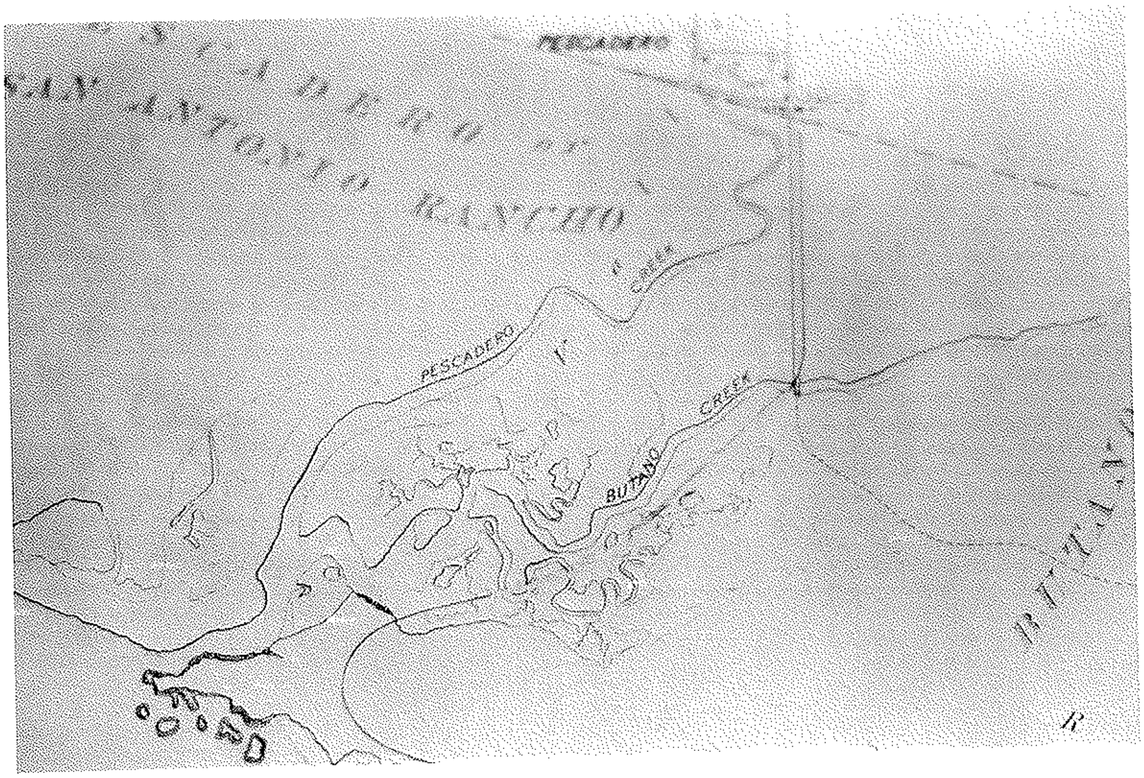


Figure 58. A 1874 map showing the route of a proposed Pescadero Railroad (California State Archives, Sacramento).

Figure 59 shows the original extent of the marsh prior to the 20th century.

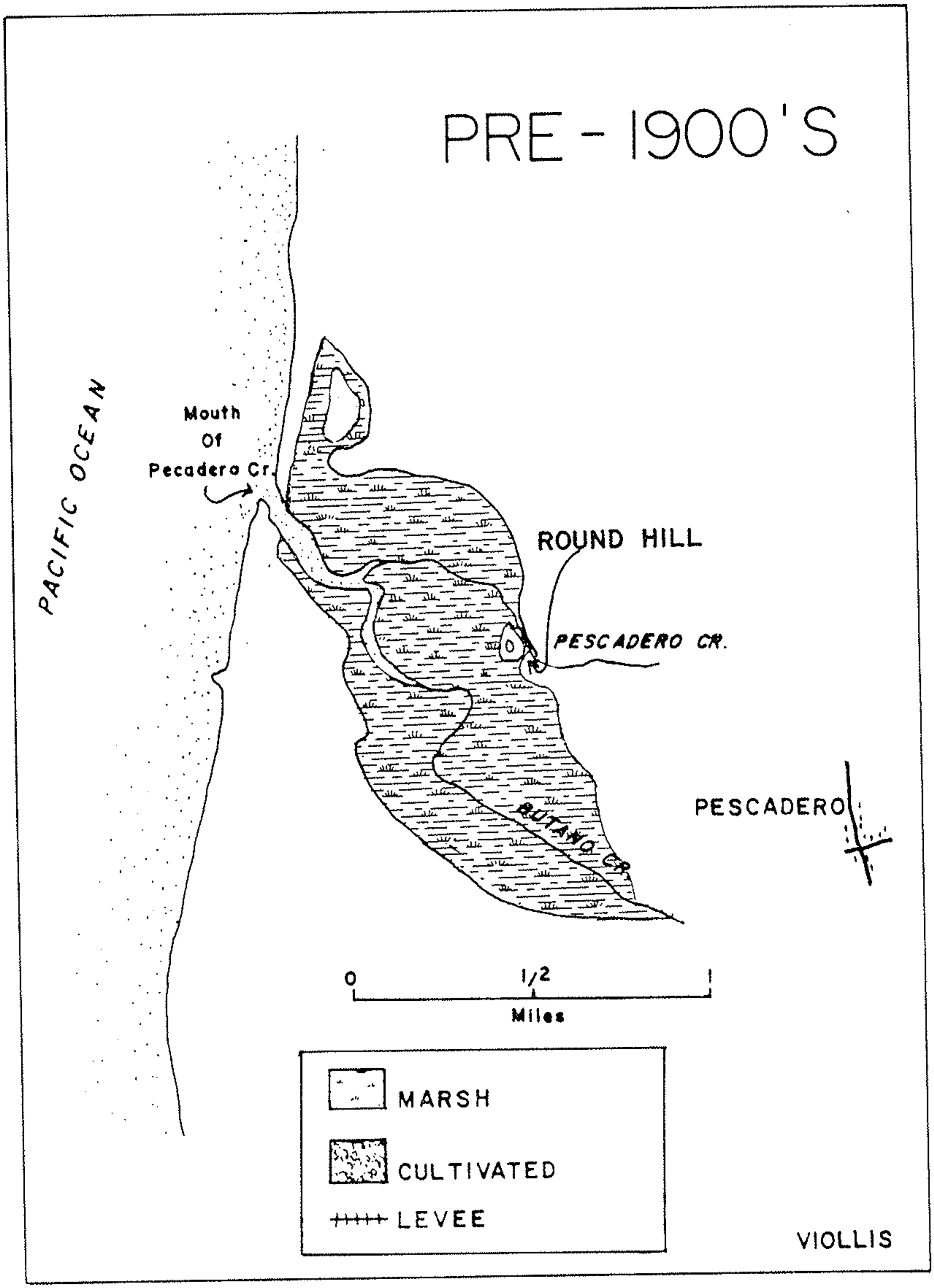


Figure 59. The boundary of the marshland as it appeared to the map-makers in 1854.

1920s. The first air photos of the marsh were taken in the late 1920s, and make up the mosaic seen in Figure 48. It is difficult to discern if there are levees in this photo, however cropland appears to follow the configuration of the marsh as seen in the 1854 topographic map. Some minor levee construction could have taken place in the vicinity of Round Hill where cultivation was in progress. But major alteration of drainage channels and marsh reclamation had not begun in the 1920s.

A dirt road did extend from the town to the beach, near the southern fringes of the marsh. A wooden bridge was built along this road in the vicinity of the present fire station (oral communication, Frank Bell).

Many of the prominent ponds south of the confluence were still visible in the 1920s as they were in the 1850s (Compare Figure 48 and Figure 57).

The north pond and the north end of the marsh were connected, and water flowed between them. There was a time in the twenties when the southeastern corner of the marsh was used as a baseball field and race-track. This was possible due to the natural drainage of the land during times of low runoff and little rainfall.

1930s. Judging from the air photo dated 1931 (Figure 60), there appears to be little change in the marsh between the 1920s and 1931. The most obvious change is the disappearance of the sand from the north end of the marsh. The same amount of land is under cultivation, with the possible exception of newly plowed land at the base of the large eucalpytus groves.

The 1931 air photo is remarkable in its clarity, and shows many of the drainage channels which are visible on the 1854 topographic survey.

Figure 60. A 1931 air photo of the study area (from the Fairchild collection located in the Geology Department at Whittier College, California).

This photo also gives a clear picture of the delta system which has evolved since the recent rise in sea level.

The north pond and the north end of the marsh are still connected and water flowed freely. Bruce Elliot comments on hydrology of the marsh prior to the 1940s. "Prior to the 1940s high summer tides would often overtop the sandbar blocking the mouth of the creek bringing significant quantities of seawater into the marsh. The water would flow through the area currently occupied by the north pond and the north marsh and even protrude well up into Pescadero channel, but eventually would undergo mixing with freshwater from runoff and be flushed back into the ocean with the next water runoff" (Elliot, 1975).

With the possible exception of added sediment due to logging and agriculture, human activity did little to change the nature of the marsh prior to the 1940s. Figure 61 shows the relationship between marsh and adjoining cropland as it appeared in the 1920s and 1930s.

1940s. The 1940s proved to be the time with major changes to the marsh occurred. A bridge was constructed across the mouth of Pescadero Creek, and Highway One was extended north across the dunes at Pescadero Beach.

An earth dike now separated the north pond from the north end of the marsh, cutting off circulation between these areas.

A major system of levees and channels was constructed and the reclamation of land southeast and northwest of Round Hill had begun (Figure 62). The increase in cropland and reduction of marshland is evident in this 1943 air photo.

An interesting feature in Figure 62 is the remains of a prominent

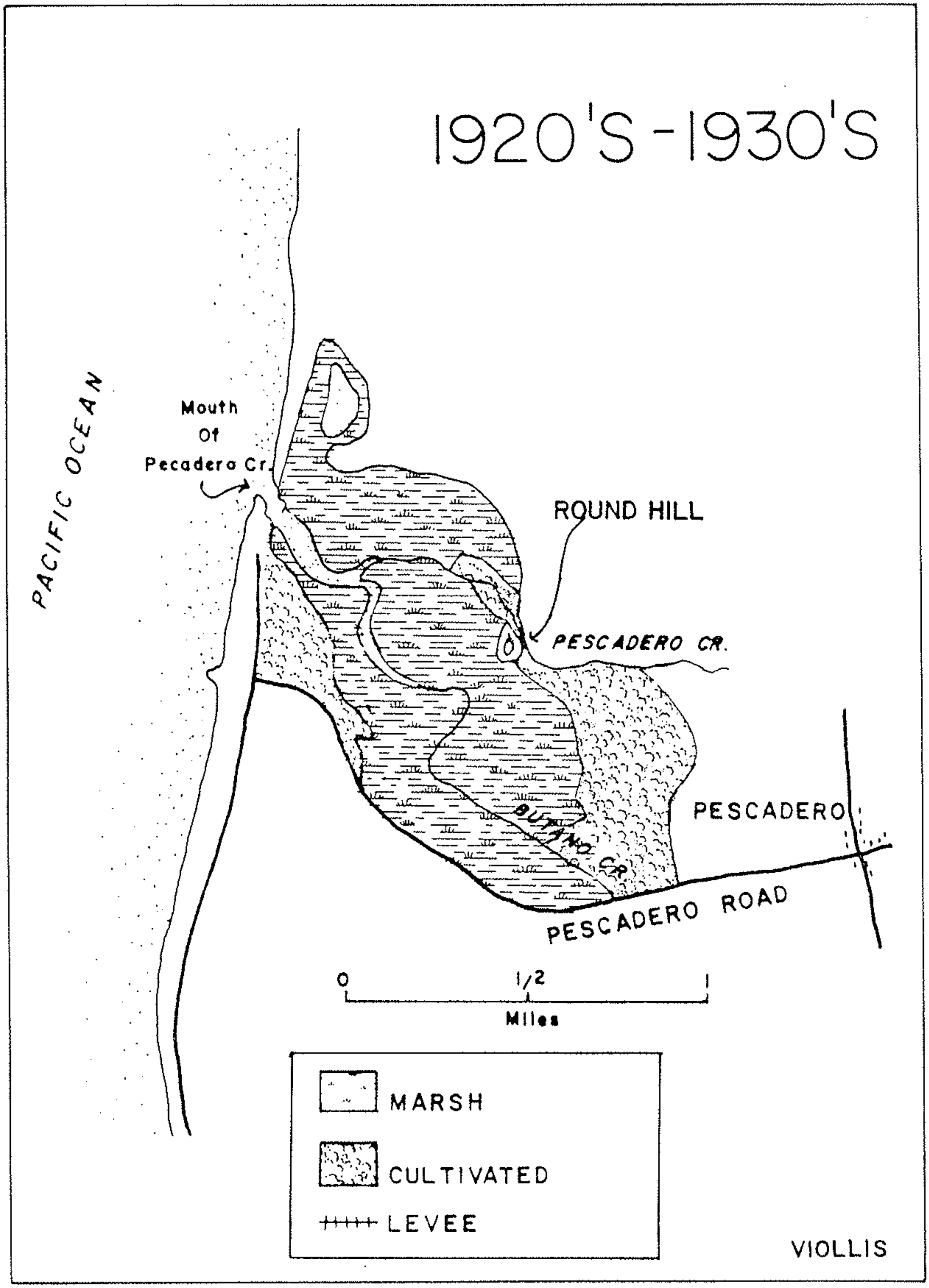


Figure 61. Map showing some reduction in marshland, as well as road construction. These changes took place in the early 1900s.

Figure 62. A 1943 air photo of the study area. Many manmade levees and channels were constructed during this decade. Notice the remnants of natural drainage channels in the cropland just southeast of Round Hill.

system of drainage channels south of Round Hill. These features are clear evidence of the reduction in marshland during the modern era.

The larger ponds south of the confluence were still visible in the forties as they were on earlier maps and air photos.

Pescadero Road, once a dirt road extending from the town to the coast highway, was widened and paved sometime during the late 1930s or early 1940s.

Figure 63 shows the invasion of cropland into drained marshland as well as the location of levees and overall marsh reduction.

1950s and 1960s. The 1950s was a decade when the greatest percentage of marshland was drained and cultivated. A large tract of land which borders the south end of the marsh along Pescadero Road, was converted to farmland (Figures 64 and 65). A parcel of land northwest of Round Hill was under cultivation.

However, in the late 1950s and throughout the 1960s, some marshland cultivated in the 1940s was left fallow, and a general reduction in cultivation of marshland occurred.

The drying up of marsh ponds was a significant change which occurred during the 1950s and 1960s. This phenomena was observed by studying a series of air photos taken during the past thirty years.

Duck clubs existed within the privately owned portions during these latter decades, although hunting is almost non-existent today. Pheasant raising was also undertaken for a time within the marsh.

1970s. During the present decade large parcels of privately owned marshland have been bought by the State. Plans to purchase the

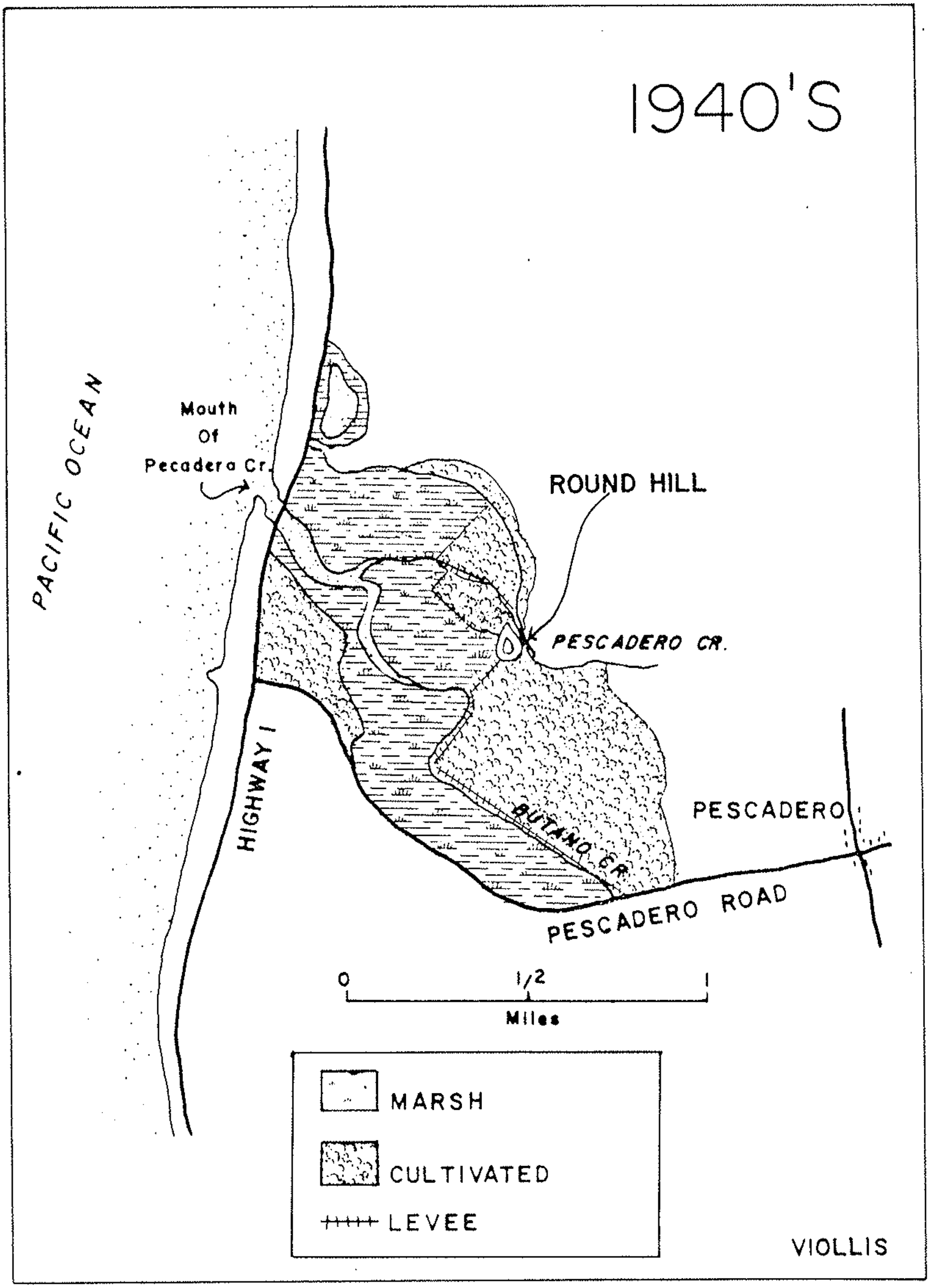


Figure 63. Map showing levees and increased marsh reclamation as it appears on 1940 air photos. The addition of Highway One to the area brought major changes along the dunes.

remaining parcel of marshland (132.25 acres) is in progress; soon a total management program can begin. Some suggestions for the management of Pescadero Marsh will be made in the next chapter.

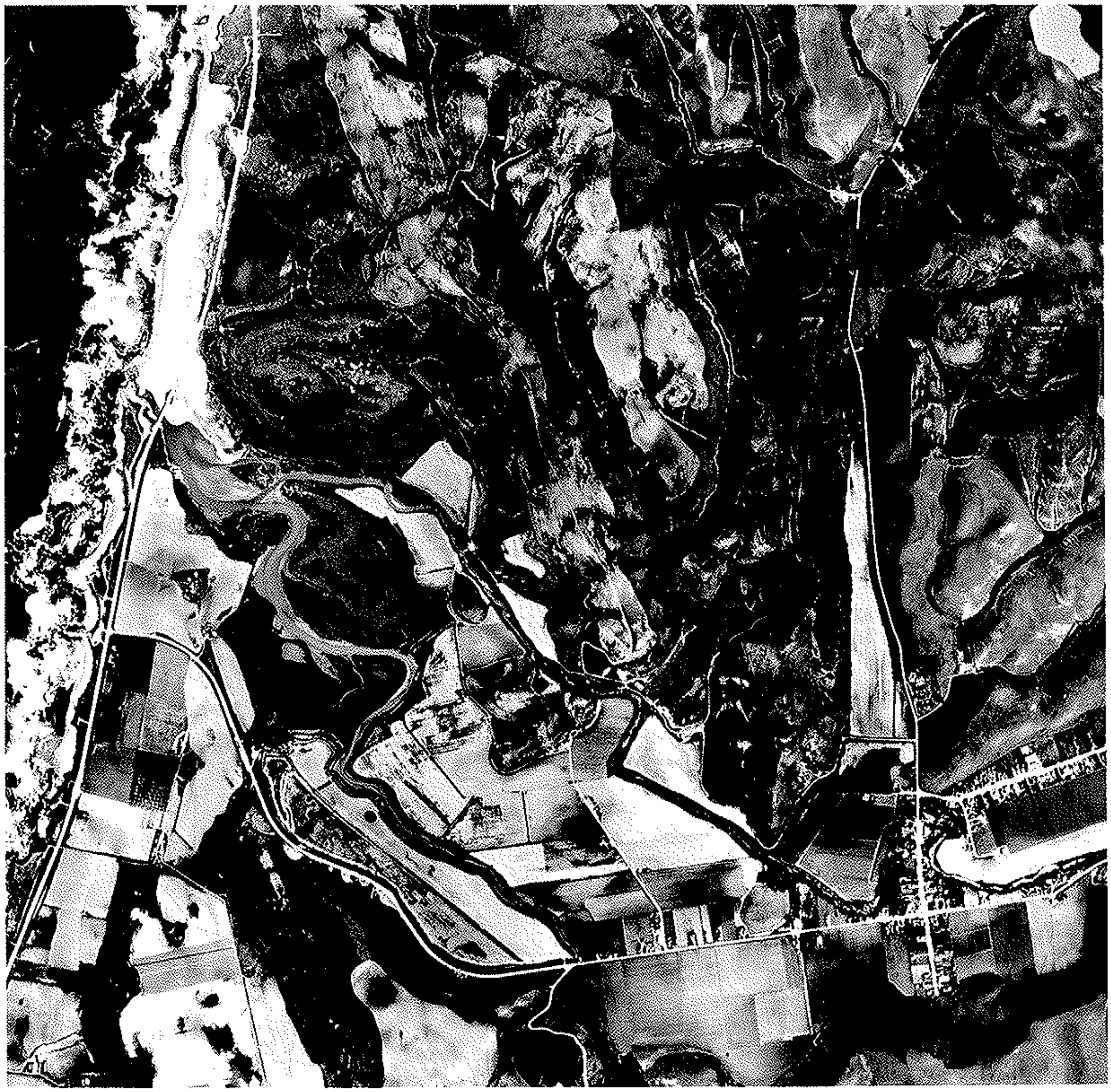


Figure 64. A 1953 air photo of the study area. It was in the early 1950s that the greatest percentage of marshland was converted to cropland.

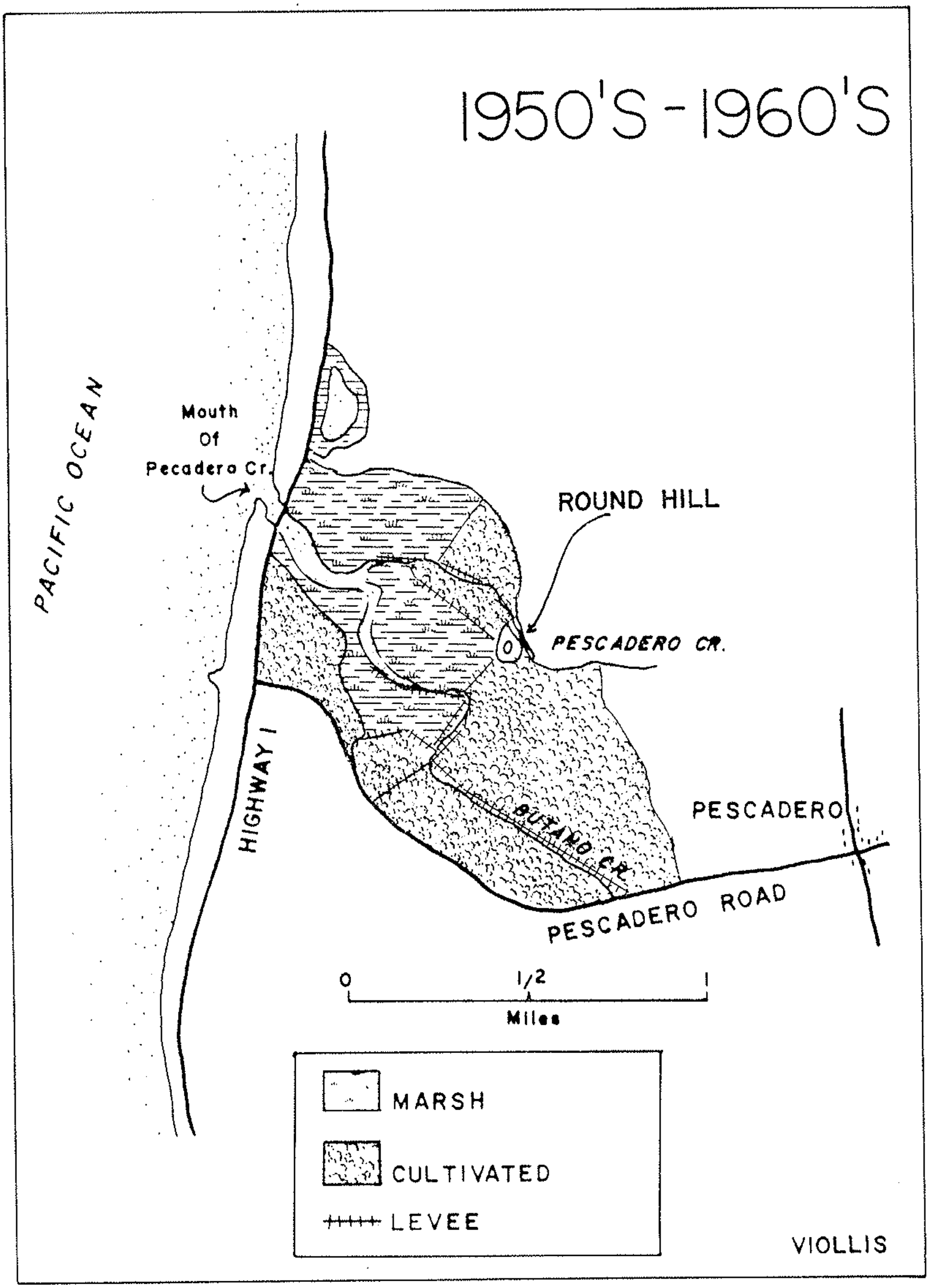


Figure 65. Map showing major encroachment of cropland upon marshland.

CHAPTER 5

SUMMARY

Pescadero Marsh: A Sequential Evolution

The present physical and biological conditions at Pescadero Marsh are the result of long periods of evolution. The events which formed this marsh are predictable and follow natural and cultural patterns observed in similar environments elsewhere.

The following sequence of events have occurred during the past two million years:

1. Fault movement over the past two million years, along with the removal of ancient sandstones and siltstones by stream erosion, have created the present valley at Pescadero.

2. During the last interglacial low stand of sea (15,000 years ago), base level was some 330 feet below its present position. Streams flowed through the lower Pescadero Creek Valley, but the valley was graded and more V-shaped, as stream energy adjusted to a lower base level. The fluvial waters entered the ocean some 15 miles west of the present shoreline. Pescadero Marsh and the aluvial floodplain did not exist.

3. Worldwide melting of continental and alpine glaciers during the past 15,000 years has raised the level of the sea to its present

position. However, the rate of sea level rise during the past 15,000 years has not been constant, and it wasn't until 6,500 years ago that the oceanic waters invaded the depression at the present site of Pescadero Marsh.

4. During the period which followed, an estuary was formed as the sea extended into the valley. Stream energy decreased as the base level approached its present level about 5,000 years ago. Then sediment began to accumulate in the lower Pescadero Valley.

5. During the next two thousand years sediment continued to be deposited, raising the elevation of the valley floor. Mud flats were probably extensive, as were the drainage channels which meandered across them.

The agents of water, wind and animals (chiefly birds) transported seeds from distant points. These seeds established the pioneer plants which constituted the first marshes. The pioneer plants, once established, further trapped sediment raising the level of the flats and young marshes. New habitats were created providing a more diverse group of plants and animals.

Sediment continued to reach the lower Pescadero Valley from both fluvial and littoral sources. Sand, eroded from seacliffs north of Pescadero, accumulated within a relatively deep water estuary.

6. About 4,000 years ago the accumulation of sand at the mouth of the creek formed the base of the dunes which led to the formation of the present-day sand spit. Streams probably meandered across the sand and out to sea, before the main stream channel was confined to its present path. Marshes formed east of the present confluence and

estuarine circulation allowed for a marine fauna typical of a small coastal estuary.

7. During the past 3,000 years, sediment has continued to accumulate at the site of the marsh. However, the rate of sediment build-up in the marsh probably increased due to the development of a sand spit at the mouth, and the subsequent reduction in flushing action.

Marsh growth was extending westward along with the accumulation of sediment. The actual rate of sedimentation varied from day to day and year to year. Floods quickly added a large quantity of sediment to the marsh, bringing upland debris. During dry periods, little sediment was added to the marsh (other than wind-blown sand) and the evolution slowed.

It was probably during this period of time that the Indians utilized the rich variety of food sources. The mouth of Pescadero Creek was still deep enough for a variety of marine mammals to enter. The sea had been at its present level for approximately 2,000 years, time enough for a diverse group of inter-tidal animals to inhabit the rocks south of the present mouth, as well as the mud flats at the marsh's edge.

Fish were probably plentiful, and the Indians trapped them with nets. Bird life was abundant, the available habitat being greater than today; there was also more water in the marsh. Potemogeton grew in the ponds and waterways in abundance--a plant which is reputed as being a valuable source of duck food (Martin and Uher, 1951).

An Indian village existed near the marsh, and at least one midden site existed in the west dunes. At times the air was filled with smoke from the fires the Indians lit to burn the native vegetation on the surrounding hills.

8. About 200 years ago, the Spanish arrived at Pescadero with horses and cattle, bringing with them exotic seeds. The marsh was close to its present elevation--a coastal wetland free of human modifications.

9. From 1769 until 1848 (period of Spanish-Mexican occupancy), very little human alteration of the marsh occurred. A road or trail constructed along a natural levee extended across the dunes to a point near the mouth of the creek. The major changes in the area were due to the grazing of livestock and the limited agriculture. New species of plants were introduced and became established on disturbed sites which bordered the marsh, and along the trail in the center of the marsh. The animal life remained plentiful; fishing and hunting continued to be a good source of food for the nearby residents.

10. In the mid-1800s, the first American settlers arrived, bringing additional exotic plants, as well as the practice of commercial agriculture and large scale logging. These two enterprises led to increased sediment transport to the marsh and the eventual reclamation of much marshland. Farming extended up to the edge of the natural marsh; some draining and filling had probably begun.

The increase in the number of alien plants added to the flora of the Pescadero region. Their seeds would later establish on the levees, roads and trails that were to be built.

During the late 1800s, the fishing and hunting were still considered to be good. Groves of *Eucalyptus* were first planted in the area, and the farming and grazing of lands surrounding the marsh continued.

11. The twentieth century brought the end of pristine conditions at Pescadero Marsh. Present conditions at the marsh are a result of a number of events which occurred during this period: modern logging in the basin; increased agriculture and increased water usage; the construction of roads, levees and a bridge; and the more recent recreational and educational use of the marsh. Although natural evolutionary processes normally lead to the extinction of marshes, these human modifications (during the past 50 or more years) have had tremendous effects upon the evolution of Pescadero Marsh.

The decline in the number of migrating fish, the disappearance of marsh ponds, together with turbid waters and the silting-in of channels in the lower Pescadero and Butano Creeks, are sufficient reasons for the implementation of a comprehensive management program at Pescadero Marsh.

Marsh Management

At the present time, the last privately-owned portion of marshland at Pescadero is about to be purchased by the State of California. What remains of the original marsh will be preserved as a refuge for wildlife.

There has been a long history of proposals and recommendations, mostly by private citizens, for the proper management of Pescadero Marsh. Concerned people have written letters to State and local officials, as well as to private land owners, expressing the great need for a sophisticated management program.

The dream of many appreciative individuals is near to becoming reality. The last 132.25 acres of privately-owned marsh will soon become part of the total preserve, and the long awaited marsh management program can begin.

Unless some unforeseen natural catastrophic event occurs, Pescadero Marsh will eventually be transformed into a coastal meadow. The disappearance of marsh ponds, reduced fish migration, and the general silting-in of waterways during the past fifty years, indicate that this transformation is progressing at a rapid rate. The alternative to this natural and human-induced destiny, is human interference (management) in order to preserve the special ecosystem of a coastal salt marsh.

We are faced with a philosophical question: whether to manipulate physical conditions, as they presently exist, to achieve a more productive and permanent marsh environment; or to allow the natural morphological process to proceed leading to the extinction of the marsh.

Part of the problem in responding to this question is that it is difficult to determine how much time remains until siltation of the lower marsh and delta system obliterates the habitat essential for wildlife. If we choose to manipulate the marsh system to enhance the quality of life, we may be faced with the task of choosing one habitat over another. If we decide to reverse the evolutionary process and initiate a "holding action" at the marsh, this marsh may not respond favorably to the manipulations. The cost to undertake any effort will also be significant.

The overriding factor may be the fact that there are very few coastal wetlands remaining. We cannot allow this very important refuge to succumb. It seems reasonable that we take an active role in maintaining a productive marshland at Pescadero.

Discussion. Water is essential to the health of marshland, and the Pescadero basin and marsh have had recent water problems. Increased pumping of water upstream has reduced stream flow, and minimum flows need to be maintained during the dry season.

The observations made in August of 1978, indicate that subsurface pools of denser saline water exist within the marsh complex (Figure 10). Continuation of these conditions could lead to stagnation of bottom waters resulting in oxygen depletion--a situation unsuitable for aquatic life. Flushing action is also reduced, allowing for the concentration of toxic wastes. If we are to enhance the quality of life at Pescadero Marsh, we must develop a comprehensive water supply plan for the entire watershed.

Siltation and increased turbidity along Pescadero watershed and marsh system has had detremental effects on fish and wildlife. Past logging and agricultural practices in the basin have added a substantial amount of silt to the streams, thereby reducing the number of migrating fish (Figures 49, 50 and 51). "Siltation is one of the most severe problems occurring in stream habitats, especially in streams utilized by salmon and steelhead" (Johnson, 1976).

Siltation smothers fish eggs, depriving them of essential oxygen. Silt cements gravel together, preventing adult fish from digging nests.

The amount of light reaching the bottom is also reduced, inhibiting the growth of algae, a basic link of the aquatic food chain.

Alteration of streambeds and waters by siltation and turbidity not only affects the fish life and aquatic insects, but the birds and mammals which feed on them.

To initiate year-around tidal flushing at the mouth of Pescadero Creek may be an expensive project. However, it would probably enhance the dwindling anadromous fishery; it may also lead to the re-establishment of some mollusks and marine invertebrates. It would also result in less flooding in the lower channels and lagoon area, with increased mud-flat exposure. However, salinity intrusion would move further upstream unless fresh water flows were increased. A study should be undertaken to determine the cost and potential effects of exposing the lagoon to greater estuarine circulation.

The destruction of the dunes along the beach and near the marsh is escalated during the weekends and summer months. Signs do not appear to have significant effect on visitors; the trampling of dune vegetation and the presence of unleashed dogs in off-limit areas continues. Temporary fencing of dunes allowing damaged vegetation to recover is a partial solution. However, with increased use of the area, a permanent ranger may be essential.

The following recommendations for the management of Pescadero Marsh are the result of three years of my research, as well as a survey of recommendations presented by Dr. Lawrence C. Binford of the California Academy of Sciences; William Anderson, retired wildlife manager for the California Department of Fish and Game; Bruce Elliot of

the California Department of Fish and Game; and my friend, Peter J. Metropulos of Belmont, California.

Recommendations.

1. The development of a comprehensive water supply for the entire watershed and marsh complex is essential.

2. Periodic testing of water in the lower creeks and marsh is necessary in order to determine oxygen levels, salinity, and the monitoring of toxic substances.

3. Many of the levees need to be rebuilt or removed. The hydrology of the marsh will change with the manipulation of the levees. Construction of a model may help predict hydrologic changes in the marsh. A model may also be used to study the feasibility of dredging the mouth of the creek.

4. There is a need for a full time ranger at Pescadero Marsh and Beach. A headquarters and interpretive center could be constructed in one of the older farm houses recently purchased by the State.

5. Signs are useful for off-limit areas. They are presently used as an interpretive device in a few locations. Their use should be limited, because overuse distracts from the natural beauty of the landscape.

6. Some dunes may require temporary fencing in order to rehabilitate areas of damaged vegetation.

7. A system of trails in the marsh is necessary for visitors to observe and enjoy the unique flora and avifauna. Before expanding the trail system, however, sensitive areas should be placed off-limits.

Metropulos (Appendixes A and B) outlined the areas of nesting birds; he also noted that the north pond is less sensitive to human activity. A trail from the town through the marsh, along Pescadero Creek (upon the central levee) could be opened to limited access; in addition to the trail around the north pond. The top of Round Hill is an excellent spot to observe the marsh.

Levees make "natural trails" with good observation points. However, many sections of these levees, especially in the southern end of the marsh, intrude on sensitive habitat. Any expansion of a trail system must take in consideration the critical flora and fauna habitats.

8. Parking lots for cars, recreational vehicles and buses should be maintained west of Highway One (in those parking lots north and south of Pescadero State Beach). Some limited parking will be necessary around the interpretive center. The sight of cars, buses and vans along the gentle dune and marsh landscape is aesthetically displeasing and detracts from the natural beauty of the area.

9. An education and research program should be developed for the marsh. Studies pertaining to coastal ecology should be promoted. Development of interpretive programs for weekend visitors and school groups should be a priority.

10. Specific research needs to be done in the following areas: (a) census of invertebrates, reptiles and mammals; (b) continuing annual census of plants and birds; (c) additional pollen studies to determine previous climatic fluctuations; (d) deep cores to bedrock and additional Carbon 14 dating of marsh deposits to determine sea level changes during Holocene times; and (e) survey of archaeological potential in the lower Pescadero and Butano Creek valleys.

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APPENDIX A

A BREEDING BIRD CENSUS

By Peter J. Metropulos

Study Objectives

The major objective of the study was to make a careful census, and to plot the locations, of birds nesting within Pescadero Marsh. This information would allow one to recognize the areas most crucial for nesting, and would provide an inventory of nesting pairs. The value of this data may be realized in the following ways:

1. As a source of data for future planning of human use of the marsh. Recognizes critical areas, those to be protected.
2. As an Index of Abundance and Diversity of birds which may be used in future studies to see if changes in avian composition or abundance occur since this time.
3. As a Supplement and updated report to those previously made concerning Pescadero Marsh.

Study Methods

Visits were made on seven days during the breeding bird season of 1978: May 29 and 31, June 17 and 27, July 11, 18, and 25. On each visit different portions of the marsh were walked and nesting pairs of birds counted and their location plotted on a detailed map of the study area. As an aid to censusing, the study area was subdivided into smaller areas each with different vegetational characteristics, and these areas were given numbers (See Figure 66).

Determination of birds which were nesting was made as follows: Any bird whose active nest was located, whose young were observed, or who were obviously territorial, were considered as breeding birds. The location of each such pair of birds was plotted on the Breeding Bird Map (Figure 66), and the species of each designated by a number on the map (See Table II).

In addition to these census visits, several "spot checks" of the entire marsh were made on other dates, both previous to, and during, the study period.

Results

A total of at least three hundred and sixty-nine (369) pairs of breeding birds were counted and their locations plotted within Pescadero Marsh. Of these 369 pairs, a total of forty-three (43) species of birds were represented (See Tables II and III). This is a very high density and diversity of breeding birds, and few areas of coastal California can boast such high productivity.

The major bird groups utilizing the marsh as a nesting area include ducks, rails, aquatic-oriented songbirds, herons. The smaller songbirds occur in the greatest numbers and have the widest range in the marsh. The larger species are scarcer, requiring larger territories and stricter requirements for nesting sites. The ten most abundant nesting species in the marsh are listed below, in order of abundance. Their percentage of total nesting pairs is given.

Long-billed Marsh Wren	(25% of total nesting pairs)
Song Sparrow	(23%)
Common Yellowthroat	(10%)
Savannah Sparrow	(8%)
American Goldfinch	(3%)
Mallard	(3%)
Redwinged Blackbird	(2%)
White-crowned Sparrow	(2%)
Cinnamon Teal	(2%)
Wilson's Warbler	(2%)

It should be noted that this study was initiated at the peak of the nesting season, and many birds undoubtedly nested before the censuses were begun, and therefore were not counted. With this in mind, the numbers included in this study should be considered to represent an <u>absolute minimum of the actual number of birds</u> nesting within the marsh.

Table III illustrates the productivity in terms of numbers of breeding pairs in each of the designated areas of the marsh. Listing the areas in order of density, one can see which are most crucial to bird nesting. Numbered areas are listed below, followed by the percentage of total pairs nests within each area.

Area #2	30% of total # pairs in study area
#3	26%
#5	16%
#1	13%
#6	8%
#4	7%

In summary, it is clear that Pescadero Marsh is an important area not only from the standpoint of a breeding bird sanctuary, but as an intact ecosystem involving a high density and variety of all forms of wildlife. This study merely documents one small part of the whole dynamic ecosystem existing in Pescadero Marsh. The marsh is not a stable environment. It is in a continually changing state, these changes caused both by artificial and natural means. If the marsh is to survive it must be managed.

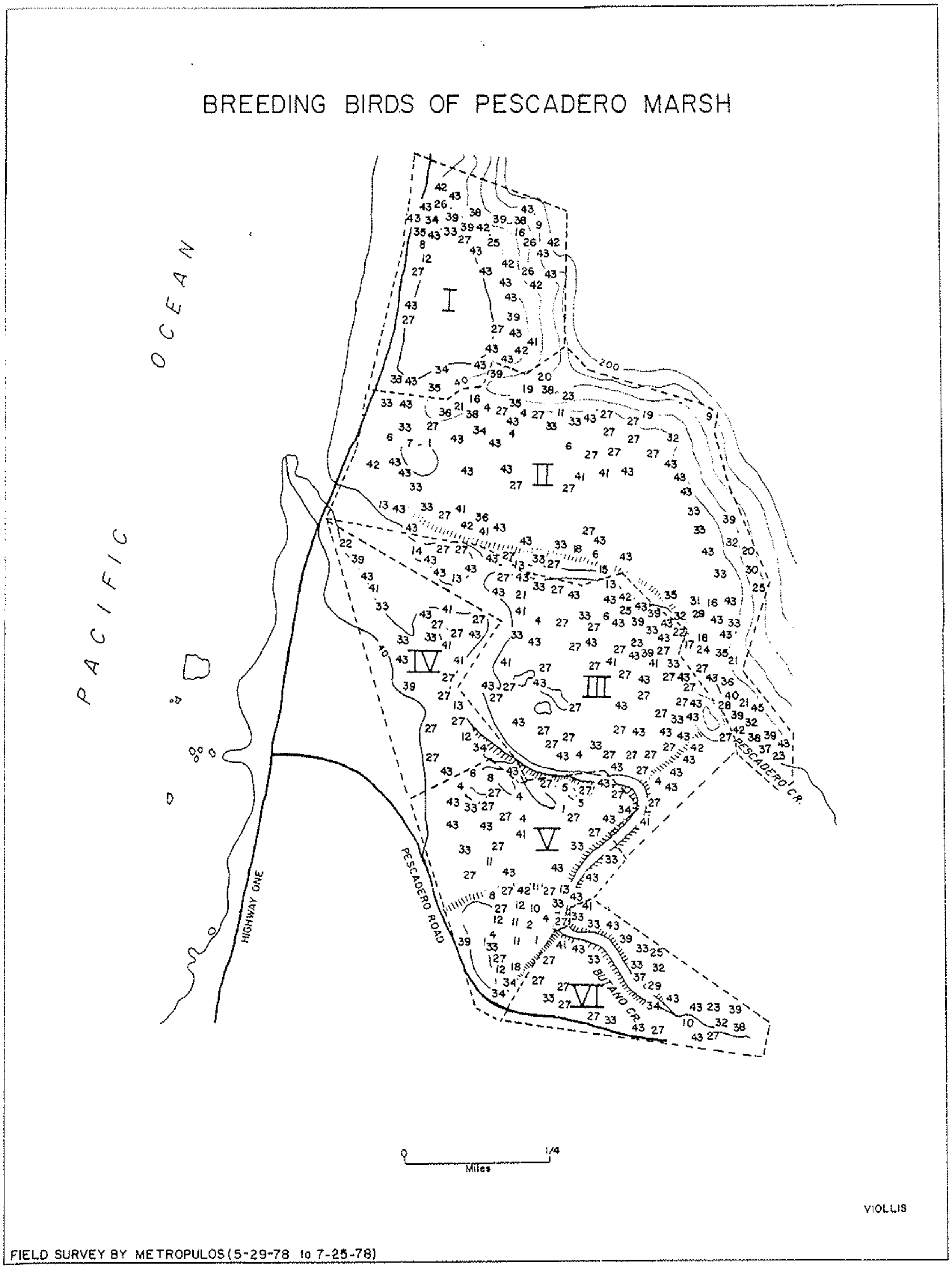
BREEDING BIRDS OF PESCADERO MARSH
PACIFIC
OCEAN
HIGHWAY ONE
PESCADERO ROAD
PESCADERO CR.
BUTANO CR.
I
II
III
IV
V
VI
200
0
1/4
Miles
VIOLLIS
FIELD SURVEY BY METROPULOS (5-29-78 to 7-25-78)

Figure 66.

Table 2

PESCADERO MARSH BREEDING BIRD CENSUS: 1978 May 29-July 25

This list is designed to accompany the Breeding Bird Map. Numbers on the map correspond to species numbered below. Species are listed in taxonomic order.

Species #	Species	Number of breeding pairs in each area						Total pairs in study area
		Area #1	#2	#3	#4	#5	#6	
1	Pied-billed Grebe	1				2		3
2	American Bittern					1		1
3	Great Blue Heron		3+					3+
4	Mallard		3	3		4		10
5	Pintail					2		2
6	Cinnamon Teal		3	1		1		5
7	Wood Duck		1				1	2
8	Ruddy Duck	1				2		3
9	Red-tailed Hawk	1	1					2
10	California Quail						1	1
11	Virginia Rail		1			4		5
12	American Coot	1			1	3		5+
13	Killdeer		2	1	1			4
14	Snowy Plover			1				1
15	Mourning Dove		1					1
16	Allen's Hummingbird	2	1+					3+
17	Belted Kingfisher		1					1
18	Black Phoebe		1			1		2
19	Western Flycatcher		2+					2+
20	Olive-sided Flycatcher		2+					2+
21	Tree Swallow		3+					3+
22	Rough-winged Swallow			1	2			3
23	Chestnut-backed Chickadee		2+				1	3+
24	Bushtit		1					1
25	Wrentit	1	1+	1			1	4+
26	Bewick's Wren	2					1	4+
27	Long-billed Marsh Wren	4	18	41	8	16	6	93
28	American Robin		1					1
29	Swainson's Thrush		1				1	2
30	Orange-crowned Warbler		1					1
31	Yellow Warbler		1					1
32	Wilson's Warbler		4				2	6
33	Common Yellowthroat	2	10	7	3	7	7	36
34	Redwinged Blackbird	3	3		1	2		9
35	Brewer's Blackbird	1	2					3
36	Brown-headed Cowbird		1					1
37	Purple Finch		1				1	2
38	House Finch	3	2				1	6
39	American Goldfinch	3	3+	1	2	1	2	12+
40	Lesser Goldfinch		1					1
41	Savannah Sparrow	2	7	10	6	2	2	29
42	White-crowned Sparrow	6	2+	1				9+
43	Song Sparrow	16	26	25	3	11	5	86

Table 3

AREA PRODUCTIVITY

Numbered areas correspond to those on Breeding Bird Map.

Area #	# breeding bird SPECIES	# total PAIRS of breeding birds
1	16 species	48 pairs
2	34 species	112 pairs
3	12 species	92 pairs
4	9 species	27 pairs
5	15 species	59 pairs
6	13 species	31 pairs

TOTAL STUDY AREA: 43 breeding bird species
369+ breeding pairs of birds

Table 4

NESTING

Miscellaneous notes on observations of active nests, young birds, or other evidence of nesting within the study area.

SPECIES	OBSERVATION	DATE
Pied-billed Grebe	One adult with 3 chicks.	May 29
" "	One juvenal seen.	June 17
" "	One adult with 2 chicks.	June 27
American Bittern	No actual nesting evidence this season, but strongly suspected of doing so. Continually present.	
Great Blue Heron	No actual nesting evidence this season, but strongly suspected of doing so. Continually present.	
Mallard	One adult with 7 chicks.	June 17
"	One adult with 10 chicks.	June 17
"	One adult with 6 chicks.	June 27
"	Since this species nests earlier in the year, probably several pairs nested before the study began, and therefore were not counted.	
Pintail	One adult with 8 chicks.	June 27
"	One adult with 6 chicks.	June 27
Cinnamon Teal	One adult with 10 chicks.	June 17
" "	One adult with 7 chicks.	June 17
" "	One adult with 10 chicks.	June 27
Wood Duck	One adult with 4 chicks.	June 17
Ruddy Duck	One adult with 4 chicks.	June 17
Red-tailed Hawk	Immatures seen on several visits.	
California Quail	Adult with brood of (#?) chicks.	July 18
Virginia Rail	One downy chick seen.	July 18
American Coot	One adult with 2 chicks.	May 29
" "	One adult with 2 chicks.	June 17
" "	One adult with 3 chicks.	June 27
" "	One pair with 4 chicks.	July 18
Killdeer	One pair with 3 downy chicks.	June 17
Snowy Plover	One pair with a two-egg nest.	
Black Phoebe	One juvenal seen.	June 17
Tree Swallow	One adult feeding juvenal.	June 17
" "	A pair feeding 3 juvenals.	June 27
" "	One adult with 4 juvenals.	June 27
Rough-winged Swallow	Two pairs nesting in holes in cliff.	June 27
Long-billed Marsh Wren	Many active nests were observed.	
Common Yellowthroat	Many juvenals were seen during the study.	
Redwinged Blackbird	Several probably nested before study period.	
House Finch	One active nest located.	June 17
Savannah Sparrow	Several juvenals seen during study.	
Song Sparrow	Several juvenals seen during study.	

APPENDIX B

A SPECIES LIST OF THE BIRDS OF PESCADERO MARSH

Compiled by Peter J. Metropulos for the Sequoia Audubon Society, November 1978.

This list was compiled from information gathered from field notes of several qualified observers, as well as various censuses, and published sightings. Detailed information is kept in the San Mateo County Bird File (in possession of author).

KEY to Abbreviations used in Species List:

ABUNDANCE

- Ab.= Abundant. Conspicuous and present in large numbers (up to several hundred at a given time).
- C. = Common. Seen regularly in moderate to large numbers (up to 200 present at a given time).
- F.C.= Fairly Common. Seen regularly in moderate numbers (up to a few dozen seen at a given time).
- Unc.= Uncommon. Regular, although not necessarily continually present, in small numbers (less than a hundred seen per year).
- R.= Rare. Seen each year in very small numbers (20 or less.
- VR.=Very Rare. Irregular. Does not occur each year, and when occurring, in very small numbers (10 or less).

SEASON

- Res.= Resident. Permanent year-round resident in marsh.
- SV= Summer Visitor. Occurs during summer months and breeds in the marsh or area immediately surrounding it.
- WV= Winter Visitor. Occurs during the winter months in the marsh, from Sept. or Oct. to March or April.
- FT= Fall Transient. Migrates through the area on route to winter range. Usually remain in marsh only a few days August-October.
- ST= Spring Transient. Migrates through the area on route to breeding grounds to the north. February-May.
- SS= Summer straggler. Individuals recorded lingering throughout the summer months. Species normally a winter visitor or transient.
- * = Breeding bird. The species regularly nests within the marsh.
- + = Irregular Breeding Bird. There are nesting records for the marsh, but does not breed each year.

HABITAT

- CS= Coastal Scrub
- E = Eucalyptus Forest
- R = Riparian thickets (willows, alders)
- W = Weedy areas (dikes, disturbed areas)
- M = Marsh. Densely-vegetated *Scirpus*, *Salicornia*, *Typha*, etc. Includes vegetated ponds and sloughs.
- O = Open Water. Large open ponds and sloughs.
- Mu= Mudflats.
- Ae= Aerial. Bird usually seen flying overhead.
- D = Sand Dunes.

SPECIES LIST

	Species		ABUNDANCE	SEASON	HABITAT	AREA#
LOONS, GREBES:	Common Loon	Gavia immer	R	WV,SS	O	Est.
	Arctic Loon	Gavia pacifica	R	WV,ST	O	Est.
	Red-throated Loon	Gavia stellata	R	WV	O	Est.,1.
	Horned Grebe	Podiceps auritus	Unc.	WV	O	Est.,1.
	Eared Grebe	P. nigricollis	Unc.	WV	O	Est.,1.
	Western Grebe	Aechmophorus occidentalis	R.	WV	O	Est.,1.
	* Pied-billed Grebe	Podilymbus podiceps	F.C.	Res.	O,M	all
CORMORANTS:	Double-crested Cormorant	Phalacrocorax auritus	R.	WV,ST	O	Est.,1.
	Brandt's Cormorant	P. penicillatus	V.R.	WV,ST	O	Est.
HERONS:	* Great Blue Heron	Ardea herodias	F.C.	Res.	O,M,Mu	all
	+ Green Heron	Butorides virescens	R.	Res.	M,R,O	2,3,5,6
	Great Egret	Casmerodius albus	Unc.	FT,ST,WV	Mu,M,O	all
	Snowy Egret	Egretta thula	F.C.	FT,ST,WV	M,Mu,O	all
	Black-cr. Night Heron	Nycticorax nycticorax	Unc.	FT,WV	M,Mu,O	2,3
	* American Bittern	Botaurus lentiginosus	Unc.	Res.	M	2,3,5,6
WATERFOWL:	Whistling Swan	Olor columbianus	V.R.	FT,WV	O,M	5,6
	Canada Goose	Branta canadensis	R.	WV,ST	O,M	5,6
	Brant	Branta nigricans	V.R.	ST,SS	O	Est.
	White-fronted Goose	Anser albifrons	R.	FT,WV	O,M	5,6
	Snow Goose	Chen caerulescens	R.	WV,SS	O,M	5,6,Est.
	* Mallard	Anas platyrhynchos	C.	Res.	O,M	all
	+ Cadwall	Anas strepera	Unc.	Res.	O,M	1,2,5,6
	+ Pintail	Anas acuta	F.C.	Res.	O,M	1,2,5,6
	Green-winged Teal	Anas crecca	C.	WV,FT	O,M	all
	Blue-winged Teal	Anas discors	R.	ST,WV,SS	O,M	all
	* Cinnamon Teal	Anas cyanoptera	C.	Res.	O,M	all
	American wigeon	Anas americana	F.C.	WV.	O,M	1,2,5,6
	Northern Shoveler	Anas clypeata	C..	WV	O,M	1,2,6
	* Wood Duck	Aix sponsa	R.	Res.	M,O	2,3
	Redhead	Aythya americana	R.	WV	O	1
	Ring-necked Duck	Aythya collaris	Unc.	WV	O	1
	Canvasback	Aythya valisneria	Unc.	WV	O	1
	Greater Scaup	Aythya marila	R.	WV	O	Est.,1.
	Lesser Scaup	Aythya affinis	Unc.	WV	O	Est.,1.
	Common Goldeneye	Bucephala clangula	Unc.	WV,SS	O	Est.
	Bufflehead	Bucephala albeola	Unc.	WV	O	1
	White-winged Scoter	Melanitta deglandi	R.	WV,SS	O	Est.
	Surf Scoter	Melanitta perspicillata	Unc.	WV,SS	O	Est.,1.
	* Ruddy Duck	oxyura jamaicensis	F.C.	Res.	O,M	all
	Hooded Merganser	Lophodytes cucullatus	V.R.	WV	O	1,Est.
	Red-breasted Merganser	Mergus serrator	Unc.	WV,SS	O	Est.,1.
BIRDS OF PREY	Turkey Vulture	Cathartes aura	F.C.	Res.	Ae.	all
	+ White-tailed Kite	Elanus leucurus	R.	WV,FT	all	all
	Sharp-shinned Hawk	Accipiter striatus	Unc.	WV,FT	all	all
	Cooper's Hawk	Accipiter cooperi	Unc.	WV,FT	all	all
	* Red-tailed Hawk	Buteo jamaicensis	Unc.	Res.	Ae.	all
	Red-shouldered Hawk	Buteo lineatus	R.	Res.	R,M,E	2,3,5,6
	Rough-legged Hawk	Buteo lagopus	R.	WV	Ae.	all
	Ferruginous Hawk	Buteo regalis	V.R.	FT,WV	Ae.	1,2
	Golden Eagle	Aquila chrysaetos	V.R.	FT,WV	Ae.	all
	+ Marsh Hawk	Circus cyaneus	Unc.	Res.	all	all
	Osprey	Pandion haliaetus	R.	FT,ST	Ae.	all
	Peregrine Falcon	Falco peregrinus	R.	FT,WV	Ae.	all
	Merlin	Falco columbarius	R.	FT,WV	Ae.	all
	American Kestrel	Falco sparverius	Unc.	Res.	Ae.	3,5,6

		Species					
GALLINACEOUS:	*	California Quail	Lophortyx californicus	F.C.	Res.	CS,W,R	2,3,6
	+	Ring-necked Pheasant	Phasianus colchicus	R.	Res.	W	3,5,6
RAILS:	*	Virginia Rail	Rallus limicola	Unc.	Res.	M	1,2,3,5,6
		Sora	Porzana carolina	Unc.	WV	M	1,2,3,5,6
	+	Common Gallinule	Gallinula chloropus	R.	Res.	M	5,6
	*	American Coot	Fulica americana	Ab.	Res.	O,M	all
SHOREBIRDS:		Semipalmated Plover	Charadrius semipalmatus	F.C.	FT,ST	Mu.	1,2,Est.
	*	Snowy Plover	Charadrius alexandrinus	Unc.	Res.	Mu.,D.	Est.
	*	Killdeer	Charadrius vociferus	F.C.	Res.	Mu.,D.	all
		American Golden Plover	Pluvialis dominica	R.	FT	Mu.	1,2,Est.
		Black-bellied Plover	Pluvialis squatarola	F.C.	WV,FT,SS	Mu.	all
		Ruddy Turnstone	Arenaria interpres	Unc.	FT,ST	Mu.	Est.
		Black Turnstone	Arenaria melanocephala	F.C.	WV,SS	Mu.	Est.
		Common Snipe	Capella gallinago	F.C.	WV	M,Mu.	2,3,5,6
		Long-billed Curlew	Numenius americanus	Unc.	FT,St	Mu,M.	2,Est.
		Whimbrel	Numenius phaeopus	F.C.	FT,ST	Mu.	Est.
		Spotted Sandpiper	Actitis macularia	R.	FT,ST	Mu.	Est.,1,2.
		Solitary Sandpiper	Tringa solitaria	V.R.	FT	MU.	1,2
		Greater Yellowlegs	Tringa melanoleucos	F.C.	FT,ST	Mu.,M	all
		Lesser Yellowlegs	Tringa flavipes	R.	FT,ST	Mu.,M	all
		Wandering Tattler	Heteroscelus incanus	R.	FT,WV,ST	Mu.	Est.,1.
		Willet	Catoptrophorus semipalmatus	C.	WV,FT,SS	Mu.	Est.,1.
		Surfbird	Aphriza virgata	R.	WV,ST	Mu.	Est.
		Red Knot	Calidris canutus	R.	FT	Mu.	Est.,1.
		Pectoral Sandpiper	Calidris melanotos	R.	FT	Mu.,M.	1,2,6,Est.
		Baird's Sandpiper	Calidris bairdii	R.	FT	Mu.	1,2,Est.
		Least Sandpiper	Calidris minutilla	C.	FT,ST,	Mu.	all
		Dunlin	Calidris alpina	F.C.	FT,ST	Mu.	1,2,Est.
		Western Sandpiper	Calidris mauri	Ab.	FT,ST	Mu.	1,2,6,Est.
		Sanderling	Calidris alba	F.C.	WV,SS	Mu.	Est.
		Short-billed Dowitcher	Limnodromus griseus	C.	FT,ST	Mu.,M.	all
		Long-billed Dowitcher	Limnodromus scolopaceus	C.	FT,ST	Mu.,M.	all
		Marbled Godwit	Limosa fedoa	F.C.	FT,WV,SS	Mu.	Est.,1,2.
		American Avocet	Recurvirostra americana	R.	FT	Mu.	1,Est.
	+	Black-necked Stilt	Himantopus mexicanus	R.	FT,SV,ST	M,Mu.	1,5,6
		Red Phalarope	Phalaropus fulicarius	R.	FT	O,Mu.	Est.,1,2.
		Wilson's Phalarope	Steganopus tricolor	Unc.	FT	O,M,Mu.	1,2,3,5
		Northern Phalarope	Lobipes lobatus	C.	FT,ST	O	all
GULLS & TERNS:		Glaucous-winged Gull	Larus glaucescens	F.C.	WV,SS	Mu.	Est.
		Western Gull	Larus occidentalis	C.	Res.	Mu.,Ae.	Est.
		Herring Gull	Larus argentatus	Unc.	WV,ST	Mu.	Est.
		Thayer's Gull	Larus thayeri	R.	WV	Mu.	Est.
		California Gull	Larus californicus	C.	WV,FT,ST	Mu.,O.	Est.,1,2.
		Ring-billed Gull	Larus delawarensis	Unc.	WV,FT,ST	Mu.,O.	Est.
		Mew Gull	Larus canus	C.	WV	Mu.,O.	Est.,1.
		Bonaparte's Gull	Larus philadelphia	F.C.	ST,FT,SS	Mu.,O.	Est.,1,2,6.
		Heermann's Gull	Larus heermanni	F.C.	FT,SS,WV.	Mu.	Est.
		Black-legged Kittiwake	Rissa tridactyla	R.	WV,ST	Mu.	Est.
		Forster's Tern	Sterna forsteri	Unc.	ST,FT,SS	Mu.,Ae.	all
		Common Tern	Sterna hirundo	R.	ST,FT	Mu.,O.	Est.
		Arctic Tern	Sterna paradisaea	R.	ST,FT	Mu.,O.	Est.
		Elegant Tern	Thalasseus elegans	Unc.	FT,SS	Mu.	Est.
		Caspian Tern	Hydroprogne caspia	F.C.	SV	Mu.,O.	Est.
DOVES & PIGEONS:		Band-tailed Pigeon	Columba fasciata	F.C.	Res.	R.,Ae.	2,3,6.
		Rock Dove	Columba livia	Unc.	Res.	Ae.	all
	*	Mourning Dove	Zenaida macroura	F.C.	Res.	R,W,M.	all

SPECIES LIST (continued)

OWLS:	Barn Owl	*Tyto alba*	Unc.	Res.	all	3,4,5,6
	+ Great Horned Owl	*Bubo virginianus*	R.	Res.	E,Ae.	2
	Short-eared Owl	*Asio flammeus*	R.	WV	M	3,4,5,6
SWIFTS:	Black Swift	*Cypseloides niger*	R.	SV,FT	Ae.	all
	Vaux's Swift	*Chateura vauxi*	Unc.	ST,FT,SV	Ae.	all
	White-throated Swift	*Aeronautes saxatilis*	Unc.	Res.	Ae.	all
HUMMINGBIRDS:	Anna's Hummingbird	*Calypte anna*	F.C.	Res.	CS,E,R.	1,2,3
	* Allen's Hummingbird	*Selasphorus sasin*	F.C.	SV,ST	CS,E,R.	1,2,3
	Rufous Hummingbird	*Selasphorus rufus*	R.	ST	CS,E.	1,2.
KINGFISHER:	*Belted Kingfisher	*Megaceryle alcyon*	Unc.	Res.	M,O.	all
WOODPECKERS:	Common Flicker	*Colaptes auratus*	Unc.	Res.	E,CS,R.	1,2,3.
	Red-breasted Sapsucker	*Sphyrapicus ruber*	R.	WV	R.,E.	2,3.
	*Downy Woodpecker	*Dendrocopos pubescens*	Unc.	Res.	R.,E.	2,3.
FLYCATCHERS:	Ash-throated Flycatcher	*Myiarchus cinerascens*	R.	ST,FT	CS,R.	2,3.
	*Black Phoebe	*Sayornis nigricans*	Unc.	Res.	all	all
	Say's Phoebe	*Sayarnis saya*	R.	WV	CS,W.	all
	*Western Flycatcher	*Empidonax difficilis*	Unc.	SV	E,R.	2,3.
	Western Wood Pewee	*Contopus sordidulus*	R.	ST,FT	E,R.	2,3.
	*Olive-sided Flycatcher	*Nuttallornis borealis*	Unc.	SV	E	2
SWALLOWS:	Violet-green Swallow	*Tachycinetta thalassina*	C.	ST,SV,FT	Ae.	all
	*Tree Swallow	*Iridoprocne bicolor*	C.	SV,ST,FT	Ae.	all
	Bank Swallow	*Riparia riparia*	R.	ST,FT	Ae.	all
	*Rough-winged Swallow	*Stelgidopteryx ruficollis*	F.C.	SV	Ae.	all
	Barn Swallow	*Hirundo rustica*	C.	SV	Ae.	all
	Cliff Swallow	*Petrochelidon pyrrhonota*	C.	SV	Ae.	all
	Purple Martin	*Progne subis*	R.	SV	Ae.	all
OTHER	Common Raven	*Corvus corax*	R.	Res.	Ae.	all
SONGBIRDS:	*Chesnut-backed Chickadee	*Parus gambeli*	F.C.	Res.	R,E,CS.	2,3,6.
	*Bushtit	*Psaltriparus minimus*	F.C.	Res.	CS,R,W.	all
	*Wrentit	*Chamaea fasciata*	Unc.	Res.	CS,R,W.	1,3,6.
	Winter Wren	*Troglodytes troglodytes*	R.	WV	R.	2,3,6.
	*Bewick's Wren	*Thryomanes bewickii*	Unc.	Res.	CS,W.	1,2,3.
	*Long-billed Marsh Wren	*Telmatodytes palustris*	C.	Res.	M	all
	*American Robin	*Turdus migratorius*	F.C.	Res.	R.	2,3,6.
	Varied Thrush	*Ixoreus naevius*	R.	WV	R.	2,3,6.
	Hermit Thrush	*Catharus guttatus*	Unc.	WV	R,CS,W.	all
	*Swainson's Thrush	*Catharus ustulatus*	Unc.	SV	R	2,3,6.
	Golden-crowned Kinglet	*Regulus satrapa*	R	WV	R,E	2,3,6.
	Ruby-crowned Kinglet	*Regulus calendula*	F.C.	WV	CS,R,W,E	all
	Water Pipit	*Anthus spinoletta*	F.C.	WV	M,Mu.,D.	all
	Cedar Waxwing	*Bombycilla cedrorum*	Unc.	WV	E	2
	Loggerhead Shrike	*Lanius ludovicianus*	Unc.	Res.	M,W.	all
	*Starling	*Sturnus vulgaris*	C.	Res.	M,E,W	all
	Hutton's Vireo	*Vireo huttoni*	R.	Res.	R.	2,3.
	Warbling Vireo	*Vireo gilvus*	R.	SV,FT	R.	2,3.
	*Orange-crowned Warbler	*Vermivora celata*	Unc.	ST,SV,FT	CS,W,R.	2,3,6.
	*Yellow Warbler	*Dendroica petechia*	Unc.	SV	R.	2,3.
	Yellow-rumped Warbler	*Dendroica coronata*	C.	WV	all	all
	*Wilson's Warbler	*Wilsonia pusilla*	Unc.	SV	R.	2,3.
	Townsend's Warbler	*Dendroica townsendi*	R.	FT	E,R.	2,3.
	*Common Yellowthroat	*Geothlypis trichas*	C.	Res.	M,R,CS,W	all
	Western Meadowlark	*Sturnella neglecta*	R.	Res.	M,W.	1,6.
	*Redwinged Blackbird	*Agelaius phoeniceus*	Ab.	Res.	M,W.	all
	Tricolored Blackbird	*Agelaius tricolor*	F.C.	Res.	M,W.	all
	*Brewer's Blackbird	*Euphagus cyanocephalus*	F.C.	Res.	M,W,R,CS	all
	*Brown-headed Cowbird	*Molothrus ater*	Unc.	Res.	R,W,M.	2,3,6.
	Western Tanager	*Piranga ludoviciana*	R.	ST,FT	E,R.	2,3.

SPECIES LIST (continued):

Species		Abundance	Season	Habitat	Area#
Black-headed Grosbeak	Pheucticus melanocephalus	R.	ST,FT.	R,E,CS.	2,3,6.
*Purple Finch	Carpodacus purpureus	Unc.	Res.	R,W.	2,3,6.
*House Finch	Carpodacus mexicanus	F.C.	Res.	W,CS,R.	all
Pine Siskin	Spinus pinus	F.C.	Res.	R,W,CS.	all
*American Goldfinch	Spinus tristis	F.C.	Res.	W,CS,R.	all
*Lesser Goldfinch	Spinus psaltria	Unc.	Res.	W,CS,R.	2,3,6.
Brown Towhee	Pipilo fuscus	Unc.	Res.	R,W.	2,3.
*Savannah Sparrow	Passerculus sandwichensis	C.	Res.	M,CS,W.	all
Dark-eyed Junco	Junco hyemalis	R.	WV	W,R.	2,3,6.
*White-crowned Sparrow	Zonotrichia leucophrys	C.	Res.	CS,W,R.	all
Golden-crowned Sparrow	Zonotrichia atricapilla	F.C.	WV	W,CS,R.	all
Fox Sparrow	Passerella iliaca	Unc.	WV	W,CS,R.	2,3,6.
Lincoln's Sparrow	Melospiza lincolnii	R.	WV	W,CS.	2,3,6.
*Song Sparrow	Melospiza melodia	Ab.	Res.	M,CS,R,W.	all

Supplemental List: Accidentals

Species which have been observed in the marsh less than four(4) times. These species should not be considered as members of the marsh's normal avifauna.

Bald Eagle Haliaeetus leucocephalus
Ruff Philomachus pugnax
Curlew Sandpiper Calidris ferruginea
Sharp-tailed Sandpiper Calidris acuminata
Semipalmated Sandpiper Calidris pusillus
Black Tern Chlidonias niger
Clapper Rail Rallus longirostris
Tropical Kingbird Tyrannus melancholicus
House Wren Troglodytes aedon
Common Crow Corvus brachyrhynchos
Scrub Jay Aphelocoma coerulescens
Western Bluebird Sialia mexicana
Black-throated Gray Warbler Dendroica nigrescens
House Sparrow Passer domesticus
Northern Oriole Icterus galbula
Evening Grosbeak Hesperiphona vespertina
Rufous-sided Towhee Pipilo erythrophthalmus
Lark Sparrow Chondestes grammacus
Chipping Sparrow Spizella passerina
Swamp Sparrow Melospiza georgiana
Lapland Longspur Calcarius lapponicus

APPENDIX C

AVAILABLE MAPS OF STUDY AREA

Name	Date	Source
Diseno of Rancho El Pescadero	--	Bancroft Library
Plat of Rancho de San Antonio (or El Pescadero)	1861	Bancroft Library
Map of the Region Adjacent to the Bay of San Francisco (State Geologic Survey of California, J. D. Whitney)	1867	California State Library
Map Showing the Line of the Pescadero Railroad from Pescadero Creek to Garzos Creek., San Mateo County	1872	California State Archives
U.S. Coast & Geodetic Survey No. 682 "Map of Part of the Coast of California from Punta del Bolsa Northward to Tunitas Creek"	1854	National Oceanic Atmospheric Administration
" " " " " "	1895	National Oceanic Atmospheric Administration
Map Showing Sub-Divisions of Part of Peninsula Farms Co. Property	1925	California Historical Society
Corps of Engineers CE. 1940, Half Moon Bay, California. 15 Minute	1940	National Cartographic Center
U.S.G.S. Topographic Map of San Gregorio, California Quadrangle. 7.5 minute	1955	U.S. Geological Survey
U.S.G.S. Topographic Map of San Gregorio, California Quadrangle. 7.5 minute	1961	U.S. Geological Survey
U.S.G.S. Topographic Map of Half Moon Bay, California. 15 minute	1961	U.S. Geological Survey

APPENDIX D

AERIAL PHOTOS OF STUDY AREA

Year	Scale	Source
1920s	-----	Ocean Shore Railroad Folio (San Mateo County Planning Department)
1931 1471, #125 & #126	1"=1320'	Fairchild Collection (Whittier College, Geology Department)
1941 6660, #394	1"=1320'	Fairchild Collection (Whittier College, Geology Department)
1943 (10-11-43) DDB=2B-156, 157, 158, 159	1: 20,000	Agricultural Stabilization and Conservation Service
1948 (4-24-48) CDF5-1,4,5,6,11, 12,13	1: 20,000	U.S. Forest Service
1953 (5-3-53) 1-60-GS-XY	1: 24,000	U.S. Geological Survey
1956 (5-27-56) DDB-2R-1,2,3,4	1: 20,000	Agricultural Stabilization and Conservation Service
1965 (5-23-65) SM 16-112	1"=1,000'	State of California Department of Transportation (District 4 Information Center)
1968 (5-15-68) 1-27 GS-VBZK	1: 30,000	U.S. Geological Survey
1970	1: 24,000	Western Air Photo (Redwood City, California)
1974 1663 126 (Infrared)	1: 24,000	U.S. Geological Survey